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# FOOD TECHNOLOGY

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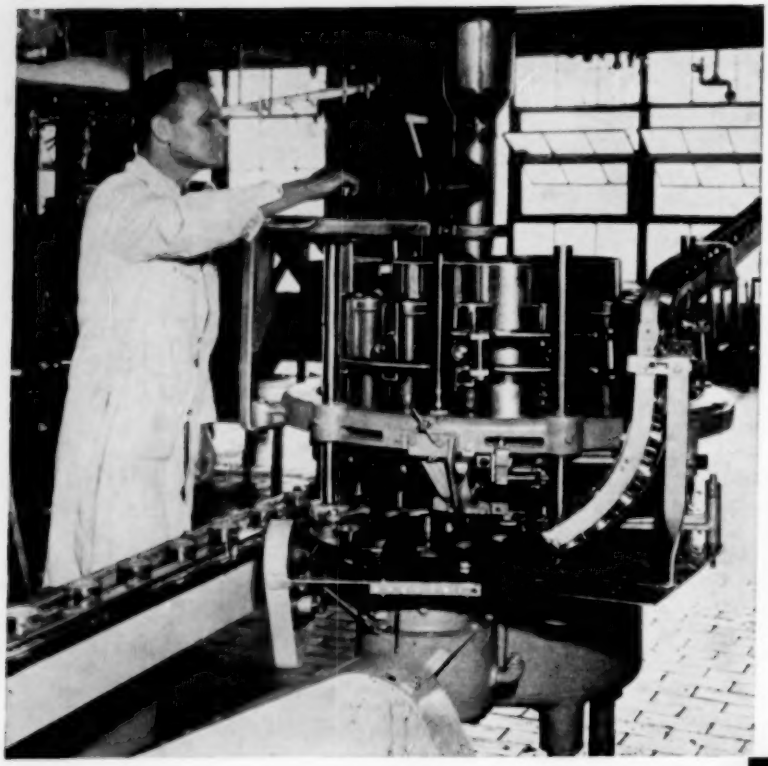

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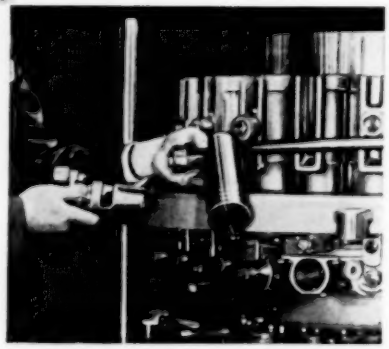

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# Factors Affecting Color and Flavor of Sauerkraut Packaged in Pliofilm Bags

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(Manuscript received May 10, 1952)

**The results of investigations concerning the effects of atmospheric oxygen, copper and iron contamination, and fluorescent light on the color and flavor of sauerkraut packaged in pliofilm bags are reported and discussed.**

Study of the factors affecting the quality of sauerkraut has been the subject of a number of investigations *(7, 8, 9, 10, 11, 12)*. In the reports the following have been cited: seasonal variations, low temperature and slow fermentation, presence and growth of certain aerobic organisms, relative levels of ascorbic acid, concentration of dissolved carbon dioxide, methods of packing, and temperature of processing and storage.

Distribution of kraut was formerly by bulk methods. This was superseded by the packing of kraut in tinned and glass containers. Recently, kraut has been packaged in small flexible packaging films. Little information is available on certain problems known to exist in the processing and distribution of kraut packaged in this manner. An investigation was made of certain aspects of discoloration and undesirable flavors resulting in this method of packaging kraut.

## PROCEDURE

Factors considered were: a, role of oxygen (air); effects of: b, copper contamination; c, iron contamination; and d, fluorescent type light. Unprocessed sauerkraut and juice having excellent flavor and color were procured at a commercial plant. The juice was adjusted with water to an acidity of 1.2%, as lactic acid. The kraut and juice were heated to 120° F. (49° C.). They were then drained, weighed into enamel trays, and fresh juice at 120° F. (49° C.) was added at a ratio of 1 part to 3 of kraut. The kraut and its juice were heated in a continuous steam tunnel at 125° F. (51.5° C.) for 10 minutes, and immediately packed in laminated 120-gauge pliofilm bags. Various treatments, subsequently described, were introduced at this point. The bags were heat sealed, and the contents were cooled quickly to 50° F. (10° C.).

The role of oxygen was studied by vacuum and gas treatments of the bags and contents prior to sealing. The procedures consisted of a, atmospheric packaging with air being retained in the bag; b, exhausting, where with special apparatus a vacuum was applied to the bags (because of the technical difficulty of attaining uniformity of treatment, it is referred to as partial vacuum); and c, nitrogen gas packing wherein the contents of the bag were flushed by bubbling nitrogen through for several minutes prior to sealing *(2)*.

The study of effects of metallic contamination was conducted by adding cupric and ferric chloride solutions to the kraut prior to sealing the bags. Copper was added at a level of 3 p.p.m., and iron at a level of 10 p.p.m. The effect of light was studied by storing one set of samples in the dark, the other uniformly exposed to light from 40-watt, soft white type, fluorescent lamps at a distance of 24 inches. All samples were placed on shelves, in a flat position in a room at 45° F. (7° C.). Examination of samples from all lots was made at weekly intervals.

The measure of ascorbic acid content of the kraut juice was taken as that of the rate of oxidation. The method used was essentially that of the A.O.A.C. procedure using 2, 6-dichlorobenzenone applied directly using the kraut juice *(1)*. The presence of copper and iron resulted in apparently greater readings, but the differences, as determined by blanks in the presence of hydrogen peroxide, were small and consistent. The ascorbic acid content at different storage intervals was plotted in graphs to illustrate the rate of oxidation. Color first was determined visually and then rated as to extent of darkening. The change in color of the kraut was measured by the Hunter Color Difference meter standardized with National Bureau of Standards plate No. 57-373-383 and SKC-SBS (Ivory 31). This plate has Hunter values of $L$, 74.9; $a_L$, −0.9; and $b_L$, 23.8 which correspond to I.C.I. notation of $Y$, 56.2%; $X$, 0.371; and $Y$, 0.381.

The samples were measured in a cylindrical cell 10.9 cm. high and 6 cm. in diameter, in which the kraut was packed to a depth of at least 2.0 cm. Determinations were made in triplicate and the averages recorded in terms of Hunter color values $L$, $a_L$, and $b_L$. In comparing the instrument measurements with visual evaluations it was found that the $a_L$ values better described the extent of discoloration which takes place in the kraut. It has been previously observed *(13)* that the *(a)* value carries about 4 times the weight of $R_d$ value which is comparable to the $L$ value. For that reason the discoloration of the kraut was determined by calculating the change in the $a_L$ value from that of the fresh kraut. The results were plotted in graphs to illustrate the rate of discoloration.

Flavor examination of the samples was made by a selected panel of 5 from the department staff applying a rank grading system.

## RESULTS

The initial ascorbic acid content of the fresh kraut was found to be 20 mg. per 100 g., and the original Hunter values were: $L$, 58.1; $a_L$, −0.1; and $b$, +19.5.

**Effect of atmospheric oxygen.** Figures 1 and 2 illustrate the rates of oxidation of ascorbic acid and of discoloration of kraut having different levels of oxygen when stored at 45° F. (7° C.) in the dark. A comparison of the two graphs indicates that discoloration is a result of an oxidation process, and that the presence of

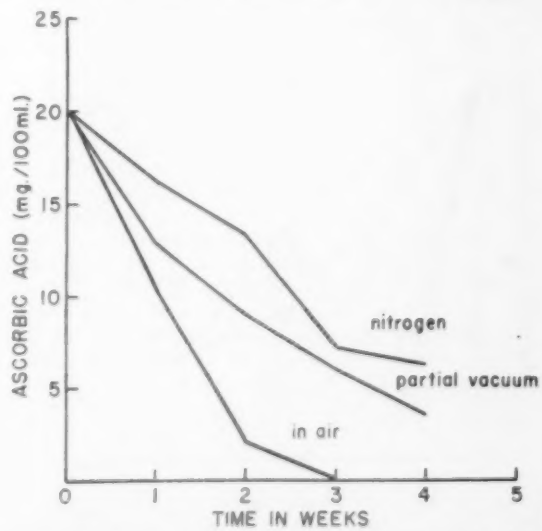


**Figure 1. Relative rate of oxidation of ascorbic acid in kraut packaged in pliofilm bags in air, partial vacuum, and nitrogen.**

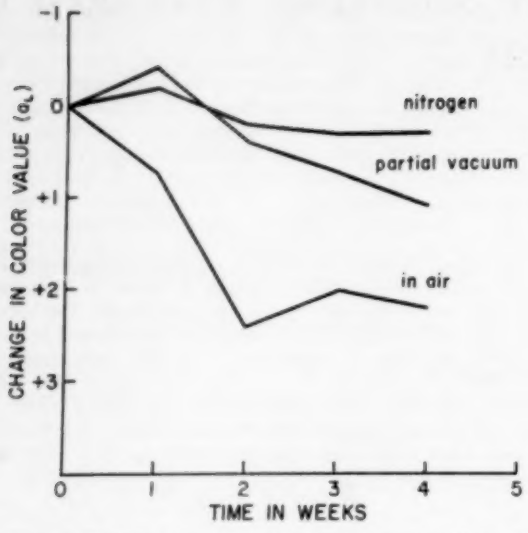


**Figure 2. Change in color value ($a_L$ as measured by Hunter Color Difference meter) of kraut packaged in pliofilm bags in air, partial vacuum, and nitrogen.**

atmospheric oxygen seems to be important to it. Most of the oxidation of the ascorbic acid occurred within the first week, while most of the change in color occurred in the second week. When air is displaced by nitrogen the extent of oxidation and discoloration is less.

**Effects of metallic contamination.** The relative effect of the metals on the ascorbic acid content and color of kraut is shown in Figures 3 and 4. In the presence of oxygen both iron and copper caused increased oxidation and discoloration; copper had a more drastic effect. At a very low oxygen level (in presence of nitrogen) ferric ions seemed to have only a slight effect whereas cupric ions continued to catalyze the oxidation. The effect of copper in the oxidation of ascorbic acid has been shown to be proportional to the square root of its concentration and a first order reaction *(5)*.

**Effects of fluorescent light.** In order to determine the effects of fluorescent light on the color of kraut packaged in pliofilm bags, paired samples were stored in the dark, and exposed to this light. The rate of oxidation of the ascorbic acid was definitely greater in the kraut exposed to the light, whether packaged in the presence of air, or nitrogen, as shown in Figure 5. The protective effect of nitrogen, as compared with air, is evident. The effect of fluorescent light on the color of the kraut was first observed as a loss of the green chlorophyll pigment, and development of a darkened

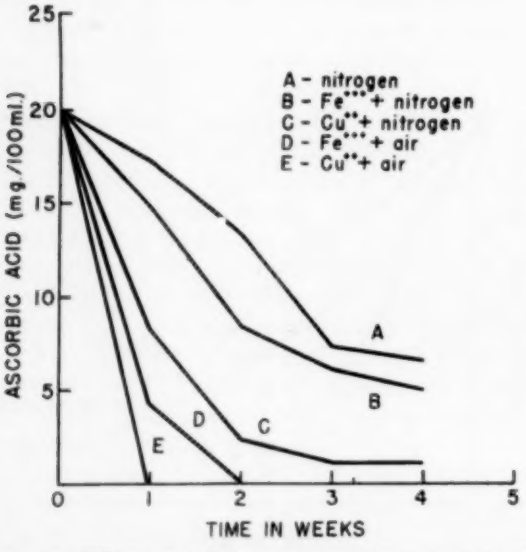


**Figure 3. Effect of added copper and iron on rate of oxidation of ascorbic acid in kraut packaged in pliofilm bags in presence of air and nitrogen.**

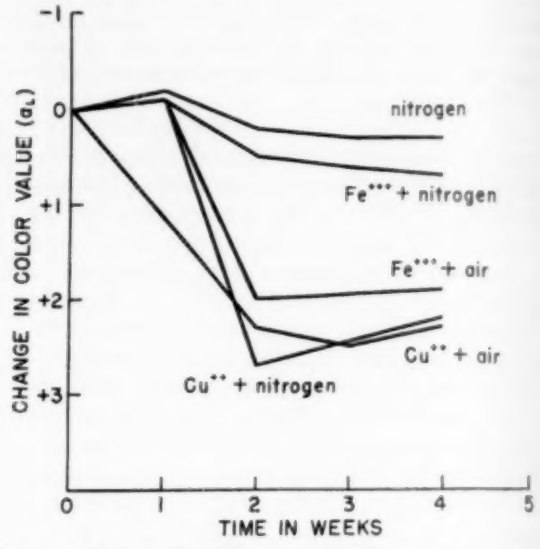


**Figure 4. Effect of added copper and iron on change in color value ($a_L$ as measured by Hunter Color Difference meter) of kraut packaged in pliofilm bags in presence of air and nitrogen.**

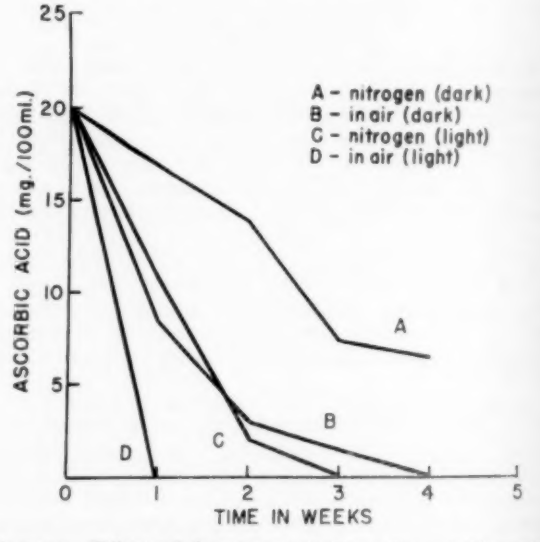


**Figure 5. Effect of fluorescent light on the relative rate of oxidation of ascorbic acid in kraut packaged in pliofilm bags with air and nitrogen.**

(grayish) appearance. This subsequently gave way to development of a tan-brown color. The relative rate of development of the browning effect in kraut, packaged in air, and in nitrogen, when stored in the dark, and in the presence of the light, is shown in Figure 6. The effects of light, and of oxygen, respectively, on kraut discoloration, seemed comparable. It was observed that fluorescent light seemed to have a browning effect in the discoloration of kraut different from that occurring in the kraut stored in the dark.

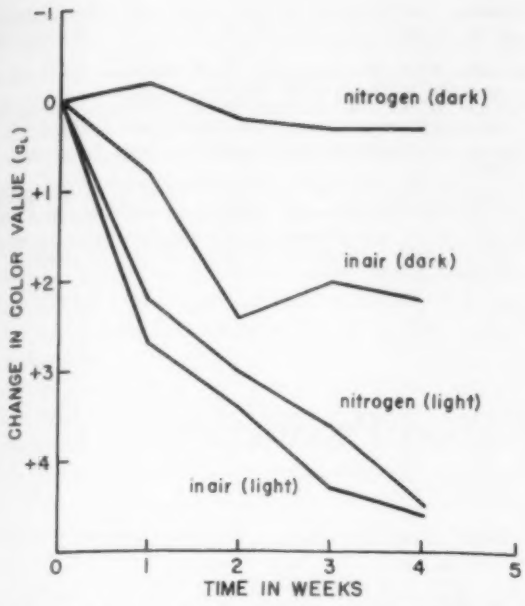


**Figure 6. Effect of fluorescent light on the change in color value ($a_L$ as measured by Hunter Color Difference meter) of kraut packaged in pliofilm bags with air and nitrogen.**

**Color value and acceptability.** A comparison was made of visual color acceptability of the processed samples and their $a_L$ values as measured by the Hunter Color Difference meter. Most samples considered acceptable by the panel had not undergone a change in Hunter $a_L$ values greater than $+1$. While only two samples, both processed with nitrogen, had acceptable color values after 4 weeks of storage in the dark (Figure 6), the color of all samples exposed to fluorescent light was rendered unacceptable after 1 week. The change in $a_L$ value for all samples thus exposed ranged between $+1.7$ and 3.1 after 1 week.

**Flavor.** Flavor acceptability of the kraut was better when oxidation of the ascorbic acid and darkening were least. The samples stored in the dark, in an atmosphere of nitrogen, were of excellent flavor quality. Exposure of the kraut to fluorescent light caused a definite activated flavor, referred to as burnt and mushroom *(15)*. This flavor developed in all samples exposed to light, whether packed in the presence or absence of oxygen. The activated flavor was more intense than any off-flavors detected in samples stored in the dark. It was easy to segregate samples exposed to light by the characteristic odor and flavor. The action of the light probably is due to an effect upon a protein fraction *(3, 4)*.

## DISCUSSION

The darkening of kraut is essentially an oxidative process as observed in a comparison of the rate of color change with that of loss of ascorbic acid. The possibility of bacteriological or enzymatic effects being responsible for such results was eliminated by study of a separate series of kraut samples heated at temperatures of 140°, 150°, and 190° F. (60°, 65.5°, and 87.5° C.). The oxidation of ascorbic acid appears to precede the darkening of color of the kraut. While oxidation of most of the ascorbic acid in the samples occurred in the first week, the darkening of color was noticeable beginning in the second. The presence of oxygen was a principal factor in both changes. Factors that catalyzed oxidation of the ascorbic acid, such as copper, similarly affected the color. In all cases where the ascorbic acid content was at a relatively high level, the color value of the kraut remained within the acceptable range. Since darkening follows oxidation of a greater part of the ascorbic acid, the level of the latter cannot be used alone as an index to evaluate color changes, or quality. Copper contamination, for example, causes a very rapid oxidation of ascorbic acid even at very low oxygen levels, and well before color change could be detected. Darkening, as caused by atmospheric oxygen, is less in the presence of ascorbic acid, which acts as an antioxidant. The elimination of oxygen should contribute to the efficacy of ascorbic acid in the protection of color. The use of nitrogen to replace oxygen appears to be desirable for the protection of the color and flavor of kraut.

The specific role of light in the browning of kraut, although not clearly determined, could be related to the formation under light of organic peroxides *(6)* which cause the oxidation of chlorophyll.

The results of this study may enable explanation of observations presented in other reports. In a normal fermentation of kraut the generation of carbon dioxide should bring about replacement of the oxygen within the first few days *(14)*. This should protect both the ascorbic acid and color of kraut. When the fermentation is completed and the kraut repacked and processed, the carbon dioxide is dissipated and replaced by air. In the presence of the latter various factors can accelerate, at different rates, the loss of the ascorbic acid and the change in color. Under these conditions the measurement of a single factor may not necessarily explain differences in subsequent behavior of the kraut.

## SUMMARY

Visual examination of color of sauerkraut was found to correlate with the $a_L$ and $L$ values as determined by the Hunter Color Difference meter. The $a_L$ value of kraut having acceptable color did not exceed $+1$.

The darkening of the color of kraut is essentially an oxidative process. Air is an important part of this reaction. Addition of copper catalyzes this process. This effect can be evident either in high or low levels of oxygen. The effect of added iron is evident only in the presence of air. In all cases when darkening occurred, flavor was impaired.

Exposure of sauerkraut to fluorescent light increases significantly the rate of its oxidation and darkening even in the absence of air. It causes also an undesirable flavor and odor in the kraut.

The packaging of sauerkraut in flexible film is satisfactory only when oxygen is removed, certain metal contamination is avoided, and exposure to fluorescent light is prevented.

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# Government Controls and Food Production[a]

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(Manuscript received May 28, 1952)

Government controls cover a very wide field. Any law or regulation which aims at minimum sanitary standards in a food processing plant or limits what materials may be put into this or that food is a control. I do not presume that you want me to discuss each of these. So I shall limit myself to government activity which affects prices or allocation of goods in the market. These are mainly price ceilings, price supports or floors and direct allocation or rationing.

In theory a price ceiling, i.e., a legal maximum price that is set below the price which would develop in a free market will: (1) discourage production, (2) lead to apparent scarcity in the market unless accompanied by an appropriate system or rationing, (3) lead to hoarding, (4) cause many types of distortions in the market, (5) build up general objection and resistance among consumers, producers, and all other parties concerned in the market. Such ceilings will in general lead to lower output both for economic and psychological reasons. To make them operate over any period of time they must be accompanied by (1) government subsidies which bring returns to producers to the necessary point to maintain output and (2) a system of rationing or allocation of the apparent short supply among those whose demands at the ceiling price exceed the available supply at this price.

When a price is held down the commodity becomes less profitable to produce. Some producer somewhere will find it more profitable to shift a part of his efforts or resources elsewhere and so curtail a part of his output. It also retards the possibility of the "high price incentive" which is likely a factor in the level of output for all farm products. There is always the possibility of loss—a crop may fail or it may be very cheap; the normal prospects are for returns which do not greatly exceed costs. But there is the possibility of high profits if one happens to have a big crop in a year of favorable prices. If there is a price ceiling, this incentive is eliminated.

When a ceiling is set it may be below the price which would balance supply and demand in the market. So there is not enough to go around and apparent shortage develops. The setting of a ceiling indicates potential scarcity. So demand may be increased. This real or apparent scarcity makes rationing necessary if an orderly market is to be maintained in cases where the market price would be above the ceiling price.

When an arbitrary price is set, there is a presumption that it is too low and that goods will become scarce. So many people hoard. These will be found at all levels—producers, consumers, distributors, processors. When soap was derationed in 1949 in France, an executive of a soap company told me that their sales of soap largely disappeared. People were apparently using up their hoarded stocks.

Ceilings always give rise to distortions in the market. Tie-in sales are an example. In OPA days corn purchases involved sales of nylon stockings, corn syrup, automobiles, even dogs. Price regulations are so drawn that some remote basing point may be chosen and so very high legal prices may emerge. All sorts of unusual margins may be added.

While consumers think they want the protection of price ceilings or politicians think that consumers want them, there is no place of record where ceilings have not become extremely unpopular. Producers obviously dislike them. All middlemen get tired of the distortions which they create in the market and of the confusion and the paper work. An exception may perhaps be made for the firms which enter the market on a black-market basis. Consumers also finally catch on to the fraudulent nature of the alleged benefits. All over the "free" countries of Western Europe controls have been dropped as conditions improved after the war.

Turning more specifically to the impact of price ceilings on agricultural production, the effect can be exaggerated. The effects of ceilings are more important in

[a] Presented at the May 19, 1952 meeting of the Chicago Section of the IFT.

market distortions than in holding down production. The production record of American agriculture during World War II under ceiling prices supports this view. True returns under ceiling prices were supplemented by government subsidies under some conditions—milk, fed cattle and soybeans are examples—but a system of ceilings inevitably involves subsidies as well as rationing as was said before. Most agricultural operations are of a long-time continuous nature involving as they do rotations, long-time breeding operations and family farms. These conditions operate against price ceilings, which are deemed to be temporary, acting as a deterrent to production.

But for operations of a short-run nature which involve a high percentage of cost items which must either be purchased or which can be readily sold for cash, ceilings would have an immediate adverse effect on production. For example, commercial broilers are a very short-run operation and involve a very high ratio of inputs to value of finished products, i.e., chicks and feed. An effective ceiling would be an immediate deterrent to broiler production. On the other hand the production of corn—our largest crop—would not likely be impeded much by an effective ceiling. It occupies a too-fixed and a too-central position in the rotation on too many farms. However, the use or marketing of corn would be completely disturbed by ceilings as our OPA experiences demonstrated.

What sort of crops or products would be adversely affected production-wise? Broilers, the finishing of beef where the chief input is purchased or salable corn, any annual vegetable crop including potatoes, probably cotton where inputs are high are examples of such products. Low price ceilings continued for long would adversely affect general farm production.

Have price ceilings been a deterrent to production in the U.S.A. since they were imposed in 1951? In general the answer is No. Farmers report they intend to plant fewer potatoes in 1952. This may be the effect of ceilings. The operations of cattle feeders may have been curtailed somewhat. Those of cattle breeders have not been. Ceilings on soybeans do not explain the somewhat reduced acreages in the corn-belt states. Hog production is being sharply curtailed but it is because of high-priced corn and a weak market for pork—not because the ceilings on wholesale pork set an effective ceiling of somewhere around $23 a 100 pounds on hogs. This past winter hogs have averaged below $17.

A better case can be made against ceilings as a disturber of markets than as a deterrent to production under American experience. But they will have some adverse production effects.

Why do we have price ceilings? The simple answer is that the Congress fearing the effects of the Korean war on the cost of living passed a law authorizing them under certain conditions. The administrative agencies set up under this law put them into effect. The whole idea was a mistake. It was the use of the wrong tool for the job. During World War II there was a huge diversion of economic effort to making war. Under these circumstances real shortages in the markets developed. Under such circumstances a system of price ceilings and rationing could be justified. But we are now engaged in no such effort. The rapid advance in prices after we entered the Korean war and again after the Chinese came in was caused by frantic buying on the part of consumers, the trade, and government agencies in anticipation of scarcities. These did not emerge, prices began to decline, the public cooled down, and the trade went to work to get rid of the excess stocks that it had accumulated. Wholesale prices have been declining for 14 months and the cost-of-living index has been level or falling for three. If any governmental action contributed significantly to this drop in prices it was the accord between the Treasury and the Federal Reserve Banks under the terms of which the Federal Reserve Banks allowed the price of long-term government bonds to seek their level in the market. This stopped the monetization of the national debt which had played a large role in the inflationary movement from June 1950 to February 1951. The reaction of the public to declining prices was to cut down on spending and to increase savings.

Now let us consider price supports. In place of trying to hold prices down, the government then attempts to keep them from falling below a certain level. The tools that may be used include direct purchases, loans on stored crops, export subsidies, import quotas.

The government is now buying eggs and cured pork for distribution to the schools in the school lunch program and other public institutions. These purchases may have some market effects and, if they cause the children to consume more of these products, they will tend to alter the pattern in use. When prices of manufactured dairy products fall to certain levels, the U. S. Department of Agriculture begins to buy for storage.

Loans are more commonly used in connection with grains and other storable staples. Farmers are offered loans against stored products at certain minimum levels. This technique has been extensively used in connection with cotton, wheat, corn, etc. During the marketing of the 1951 crop wheat was the northern grain crop for which farmers made extensive uses of loans.

The most extensive use of export subsidies is in connection with wheat. Under the International Wheat Agreement, we are obligated to sell about 250 million bushels of wheat to certain countries within a maximum and minimum range of prices. The maximum price is below the loan on wheat, so a subsidy has to be paid to carry out the agreement. This averages about 65 cents a bushel and the cost to the Treasury, i.e., to the taxpayers, is in the order of $170-180 million annually.

The major commodity which is supported by import quotas is sugar. We are a deficit country for sugar. By setting a limit to quantity imported we hold down the supply in this country to what will be absorbed at the desired price.

For wheat, an export commodity, we use the export subsidy; for sugar, an import commodity, the import quota.

What are the production effects of such supports? If no restraints are put on production, they tend to maintain or increase production. If the price is actually higher than it would otherwise be, and this is not neces-

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sarily the case, it would tend to encourage expansion of output. But since total agricultural output is relatively unstable and not very elastic, i.e., responsive to price, the over-all effect is probably not large.

It is also argued that giving the farmer assurance that prices will not fall below a certain level gives him confidence to go ahead, make investments in improving land, buying equipment, etc. So production is maintained or increased. The point turns on the avoidance of low prices. This is the position taken in England where except for horticultural products, prices of raw agricultural products, are in general fixed. The prices are both floors and ceilings. Production increased there during the war and has worked moderately higher since the war, just as it has here.

On balance it may be concluded that price supports tend to maintain or increase output. But two points should be noted.

*First*, when a price support leads to accumulation of stocks and then to the setting of acreage allotments or marketing quotas, then not only may production be reduced but also the pattern of production will be distorted so as to make for an uneconomical use of resources. For our basic crops the Secretary of Agriculture is authorized to set acreage allotments whenever supplies go above certain levels. The only sanctions imposed for non-compliance is the loss of the loan privilege.

With the approval of two-thirds of the growers, market quotas may also be imposed. Here the penalty is more severe. Production from acreage above the prescribed figure can only be sold if a heavy tax is paid. These were in effect on cotton and rice in 1950. Never was a situation more completely misjudged as demands for both these crops proved to be heavy and actual supplies were scarce. We had to impose export quotas in marketing the 1950 cotton crop. Market quotas are still in effect for tobacco and peanuts. Marketing quotas tend to hold down acreages. They may not actually reduce the crop much because planting is concentrated on the best land and every effort is made to increase yields.

Allotments and marketing quotas also distort production patterns. They are based on historical acreages and their use may tend to check shifts in centers of production to more favored locations. They may tend to maintain uneconomic cotton productions in the eastern cotton belt and to retard it on irrigated land in California. Or they may cause an increase in acreage of second-choice crops to replace the restricted crop and so create more competition for other established areas. Soybeans and corn in the Mississippi Delta are examples.

Second, while price supports may have the effect of stimulating output where no quota arrangements are in effect, they may often upset the functioning of the market. Market prices have definite functions to perform in guiding use of resources in production, in moving goods from producers to consumers, in adjusting use to supply, in guiding the formation and distribution of storage stocks. The insertion of arbitrary elements into pricing, i.e., government price supports may hamper the market price mechanisms in doing these things. Dried-skimmed milk is a highly valuable raw material which food technologists and merchandisers are going to use increasingly. Holding its price to an arbitrary minimum level may delay the development of the market for this product.

The arrangements for pricing milk have not been mentioned. Here the market order is used. After hearings the formulas used for pricing milk are prescribed. These formulas vary over the country. In Chicago they prescribe a classified price plan—fluid milk, cream, butter, etc., a base price reflecting the value of milk for manufacture, and seasonally variable premiums over this base price for the higher categories of use such as for distribution as fluid milk. These various prices are paid uniformly by all dealers and farmers are paid an average price depending on how the total supply is used. No allotments to individual farmers are permitted. What effect does this system have on production? The major defects arise from the rigidity which the method may impose. There is a lot of built-in flexibility but still there is the rigidity imposed by the time required to get orders amended.

We have considered ceilings and supports. The third way in which the government may intervene in a market is physical allocation. We have noted some instances: rationing to make ceilings work, acreage allotments or market quotas (land rationing) when price supports cause accumulation of excessive stocks; import quotas in the case of sugar. On balance all of these will tend to reduce output. We are not now making extensive use of these for agricultural products, and there is no food rationing. Market quotas are being continued only for tobacco and peanuts. Import quotas are imposed on sugar and cheese and for some unknown reason imports of butter are prohibited. Sanitary barriers such as on cattle from Mexico and Canada and beef from Argentina have economic effects but are not within the scope of my discussion. A complex system of allocations for metals is now in effect.

## CONCLUSIONS

Price ceilings will tend to retard output although the over-all effects can be exaggerated except for particular commodities with high inputs. Price supports will tend to increase output unless combined with acreage allotments and market quotas but again the over-all effects can be exaggerated. Both ceiling and floor prices will have bad effects in the markets which may tend to reduce output.

The less use made of any of these devices and the more generally we allow economic forces to guide production and markets the better off the nation and the people will be in the long run. The government will be wise to limit itself to functions which it alone can perform. For example the maintaining through the Federal Reserve System of a money market which aims at adequate but stable supplies of the means of payment.

# Recovery of Tomato Processing Wastes

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**A method is described for producing dry press cake of good quality from tomato processing wastes. The development of a process for recovering 83% of the total waste solids from a tomato juice processing plant is reported. Costs of operation are estimated and the value of the method is described.**

The average quantity of tomatoes processed annually during the period 1941 to 1950 is reported to have been 2,932,000 tons *(2)*. By far the largest part was made into juice and juice products. For every million tons of tomatoes so processed there would result about 123,800 tons of recoverable wastes having some 11,300 tons of total solids. This amounts to about 19% of the total solids in the original tomatoes.

At present only a small part of the waste solids from tomato processing is recovered. Where this is done it comprises drying only that portion of the waste which can be pressed. The disposal of tomato processing wastes is a serious problem in some areas. If they can be dried and sold for feed, it would alleviate this situation, even though the process were not profitable.

This paper describes a process developed through pilot-plant research whereby all the press cake solids can be recovered as well as 65% of the solids in the liquid wastes; enabling the recovery of 83% of the total waste solids. Since the cost of recovery will probably exceed the value of the product, such a process would be adopted only as a means of waste disposal.

## PILOT-PLANT EXPERIMENTS

The wastes from a plant processing tomatoes into juice and juice products consist of culls and trimmings from the sorting operations as well as the tailings from the juice cyclones. The former contain only about 6% solids whereas the latter contain about 15%. Our work was directed toward developing a method for recovering in so far as possible all of the solids in these two types of wastes. The first step was to obtain a high solids fraction from the culls and trimmings. This was done by chopping them and passing them through a cyclone. The tailings from the cyclone have about the same solids content as the tailings from the juice making operations. The combined tailings when pressed yielded a press cake and a dilute liquor. Drying studies were first made on this press cake. Since facilities were not available at the Laboratory, the processing of culls and trimmings into tailings and liquor as well as the pressing of tailings was done elsewhere.

The equipment used for the study included a portable, two-pass, oil-fired, rotary drier of the type commonly used for alfalfa. It was 16 feet long and 7 feet in diameter with a rated evaporative capacity of 2500 pounds per hour of water when drying alfalfa at 1200° F. (649° C.). A mixing conveyor for incorporating liquids into solids was provided as well as facilities for bagging the dried product. The assembly included the necessary pumps and conveyors as well as control and recording instruments. Figure 1 shows part of the equipment.

[a] One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

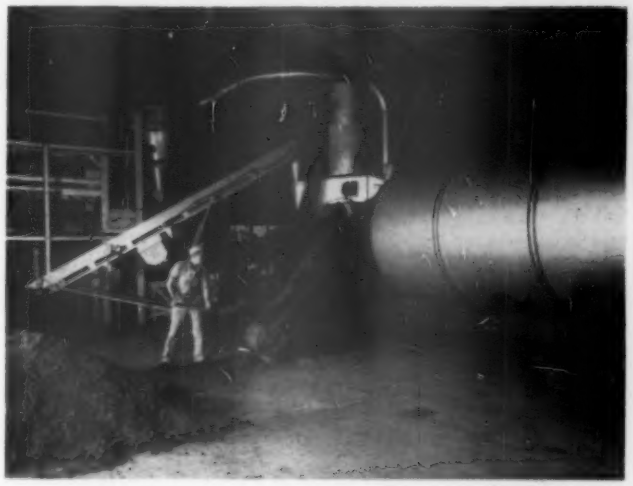

**Figure 1. Experimental drying of tomato waste.**

A direct-fired drier was tried since its use would not require a steam generating plant or impose an additional steam load on the tomato processing plant. Since press cake dried in direct-fired driers is at times dark in color and of reduced value, it was necessary to determine the conditions under which a high-grade product could be obtained with this type drier. Although the drier in question was capable of operating at a maximum inlet gas temperature of 1250° F. (677° C.) it was found that the maximum permissible temperature without discoloration was about 1050° F. (566° C.) with an exit gas temperature of 275° F. (135° C.). Under these conditions the capacity was about 3300 pounds per hour of press cake containing 63% moisture. This corresponds to an evaporative rate of about 2000 pounds of water per hour. These temperatures were found satisfactory for press cake varying from about 60-69% moisture, under which conditions the dried product had a good odor and light color, and contained about 8% moisture. A typical analysis of this product is shown in Table 1.

**TABLE 1**
**Analysis of dried press cake**

| Ingredient | % |
|---|---|
| Moisture | 8.0 |
| Protein (N × 6.25) | 22.5 |
| Fat | 14.2 |
| Fiber | 29.6 |
| Ash | 3.3 |
| Nitrogen-free extract | 22.4 |
| Total | 100.0 |

In a plant where the tailings from the food cyclone and from the waste cyclone are both pressed the liquid wastes from the plant will consist of press liquors as well as liquors from the waste cyclone. These combined liquors contain a little less than 5% solids. To be utilized they must be concentrated. Since facilities for concentration were not available at the Laboratory we used a concentrate prepared elsewhere. It contained about 30% solids which represents about the maximum readily obtainable by direct concentration. Following the practice sometimes used with distillers' wastes and in the citrus processing industry, attempts were made to dry a mixture of the press cake



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and the concentrated liquors. It was found that although a product of satisfactory appearance could be made by drying such a mixture at an inlet temperature of 1000° F. (538° C.), exit temperature 253° F. (123° C.), only a limited amount of concentrate could be incorporated with the cake without the mixture sticking in the drier and burning locally. Using this procedure the maximum utilization of waste solids would be only about 67%.

In order to increase the amount of concentrate that could be incorporated with the press cake it was found necessary to first dry the cake. Press cake dried in the manner already described proved a satisfactory base for mixing with concentrate. By this means it was found possible to increase the amount of concentrate that could be added, thereby achieving the utilization of 83% of the solids in the wastes. Chiefly because of sugars and other solubles in the mixture it was necessary to use relatively low inlet and exit air temperatures to prevent scorching the final product. With inlet and exhaust temperatures of about 550° F. (288° C.) and 235° F. (113° C.), respectively, the drier had an evaporative rate of 798 pounds of water per hour. A typical analysis of the dried product is shown in Table 2.

**TABLE 2**

**Analysis of dried press cake plus concentrate**

| Ingredient | % |
|---|---|
| Moisture | 8.0 |
| Protein (N × 6.25) | 21.0 |
| Fat | 9.8 |
| Fiber | 21.9 |
| Ash | 5.9 |
| Nitrogen-free extract | 33.4 |
| Total | 100.0 |

Incorporation of all the concentrate in the proportions in which it would occur with respect to the press cake, gave a sticky mixture which could not be dried.

A method has been suggested whereby more or possibly all of the concentrate might be used. It would be as follows: Screen the seeds from the dried press cake and cut the screen "overs," consisting largely of skins, in a rotary knife cutter in order to expose more surface area. Recombine the cut skins and seeds, mix with the concentrate and dry in the manner previously described.

## SUGGESTED COMMERCIAL OPERATION

The example given is for a waste recovery plant that will operate in conjunction with a factory making tomato juice or juice products or both. The factory is asumed to have a capacity for processing 800 tons of tomatoes in 17 hours during the peak of the season. Of course the recovery plant might obtain wastes from several factories whose combined capacities would equal 800 tons of tomatoes per day. The waste recovery plant during peak of season will produce 8.13 tons per day of high quality feed having 8% moisture. For the season, it will produce 263 tons of feed from the waste resulting from processing about 26,000 tons of tomatoes.

Figure 2 shows diagrammatically the sources and quantities of tomato wastes produced each hour during the peak of season and how these wastes are processed to make feed. It is obvious that the quantities of culls and trimmings, tailings, press cake, and liquors and their moisture contents will vary somewhat from day to day. However, the figures given here can be considered fairly typical for the area east of the Mississippi River.

**Processing culls and trimmings.** Culls and trimmings, containing about 94% moisture, come from the food processing plant at a rate of 7611 pounds each hour. These can be ground in a green garbage grinder

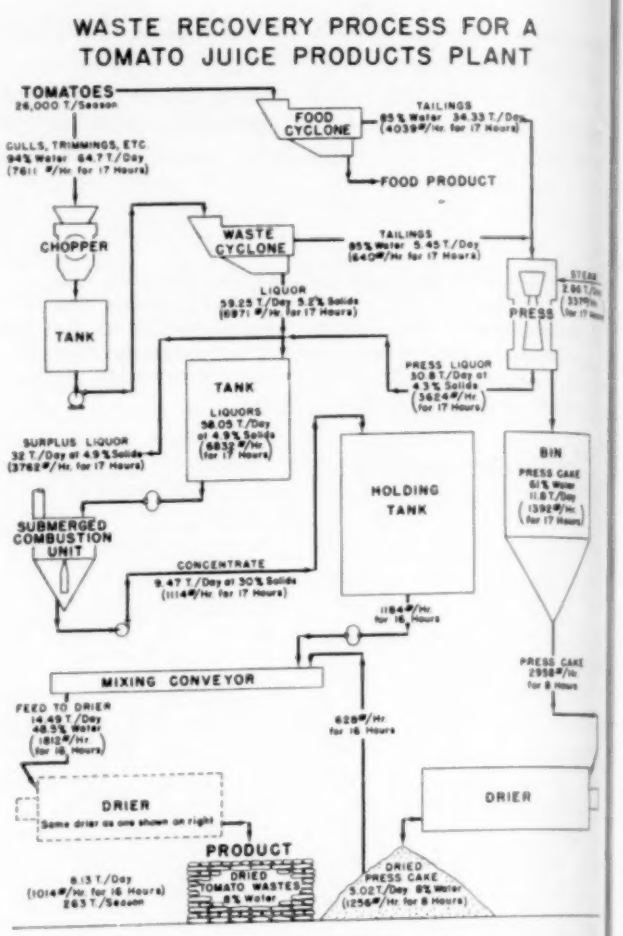


**Figure 2. Waste recovery process for a tomato juice products plant.**

and conveyed by means of a self-priming centrifugal pump to a small waste cyclone. This cyclone will produce 6971 pounds of waste liquor each hour containing 4.9% solids and 640 pounds of tailings at 85% moisture.

**Pressing the tailings.** Tailings from the waste cyclone are combined with 4039 pounds per hour of cyclone tailings at 85% moisture conveyed from the food processing plant. These can be pressed in a Zenith[b] continuous, cast-iron, screw type, pulp press equipped with stainless steel screens. Steam, at a rate of 337 pounds per hour, is injected into the waste in the press to facilitate pressing. This is the only operation in the byproducts plant where steam is used. It may be furnished by the food processing plant. The press should deliver 1392 pounds of press cake at 61% moisture and 3624 pounds of liquor at 4.3% solids per hour.

**Drying the press cake.** In order to efficiently utilize the capacity of the drier, the press cake produced during the 17-hour day will be dried in 7 to 8 hours. This will be accomplished by holding the press cake produced during the initial 9- to 10-hour period in a wooden bin 10 × 12 × 4.5 feet high with a sloping bottom. Press cake will be delivered from the bin to the drier by means of screw conveyor equipped with speed control at a rate of 2958 pounds per hour. A drier having the same

[b] Recommendation of this specific product is not implied. Products of other manufacturers may be equally effective.

capacity as that previously given will be satisfactory for drying the press cake.

**Concentration of waste liquors.** Since the waste liquors contain only about 5% solids they must be concentrated. Concentration of this material in conventional tubular evaporators poses a fouling problem. Submerged combustion is therefore suggested. The experience of others has shown that a tomato waste liquor concentrate of good color can be made by this type of evaporation. Submerged combustion units can appropriately be operated in areas where cheap natural gas is available. In the suggested installation a unit having an evaporative capacity of about 6000 pounds of water per hour will be required. A 500-gallon feed tank which will serve as a reservoir ahead of the evaporator is recommended to insure a constant feed.

During the peak of the season there will be produced hourly over and above that which can be utilized as concentrate, 3762 pounds of waste liquor of 4.9% solids. This is equivalent to about 17% of the total waste solids from the tomato processing plant. This material might be concentrated to about 30% solids and canned for use as a feed supplement for fur-bearing animals. There is a reported demand for tomato waste concentrate for that purpose. However, the cost data, reported later in this paper, do not include costs of processing this liquor.

**Mixing concentrate with dry press cake.** In order to produce a good final product, consisting of a dried mixture of tomato waste liquor concentrate and the previously described dry press cake, it is necessary to thoroughly coat the dried press cake with the concentrate. This can be accomplished readily in a mixing conveyor 20 feet long and 20 inches wide equipped with adjustable paddles 18 inches in diameter, and driven at about 44 r.p.m. with a 7½ HP motor. To insure thorough coating of the dried press cake with the concentrate, the paddles should be adjusted so that the materials will be held in the mixing conveyor for about 2 minutes.

Delivery of materials to the mixing conveyor at predetermined rates is required to insure their being mixed in proper proportions and to furnish a constant feed rate to the drier. For the proposed waste recovery plant, dried press cake, having 8% moisture, would be delivered into the mixing conveyor by means of a variable speed screw conveyor at a rate of 628 pounds each hour for 16 hours. Simultaneously, the concentrate, having 30% solids, would be pumped into the mixer by means of a positive delivery pump at 1184 pounds an hour. A screw conveyor (not shown) is used to transport the mixture to the drier.

**Drying the mixture.** Large-scale drying studies in the previously described rotary, direct-fired drier, showed that a mixture of concentrate having 30% solids and dried press cake could be dried to produce a satisfactory product when the mixture did not contain more than about 65% concentrate. For the proposed tomato waste factory, it is necessary to evaporate 800 pounds of water each hour from 1812 pounds of mixture for 16 hours during the peak of the tomato season. Hence the previously described drier has sufficient capacity to dry the mixture of concentrate and dry press cake. It will produce 8.13 tons of product each day and 263 tons each season. Since the drier can readily process the wet press cake in 7 to 8 hours, and can dry the mixture of concentrate and dry press cake in 16 hours, it is apparent that the same drier can dry both materials on a three-shift basis during the peak of the season.

## COSTS

For purposes of cost estimation the proposed waste recovery plant is asumed to operate in conjunction with an existing tomato processing plant located in Indiana, the existing plant having a capacity of 26,000 tons of tomatoes in an 8-week season. It is assumed that for the new enterprise land, roads, railroad siding, and the relatively small amount of steam required, are available. It is further assumed that the wastes from the processing plant will be conveyed to the recovery plant. The waste recovery plant will operate 550 hours per year. At the peak of operation it will produce 8.13 tons per day. The total seasonal output would be 263 tons. Since operations are carried out only during the summer, housing will consist of a structure comprising a concrete floor, no walls and a corrugated galvanized roof. Fuel for both the submerged combustion unit and the drier will be natural gas.

The total fixed capital required would be about $88,500 which figure includes the building, all equipment installed, engineering fees, and contingencies. With an additional $25,000 working capital, the total capital required for the enterprise would be $113,000. The cost to make a ton of the dried product would be about $116. This includes not only materials, labor and factory overhead, but interest on working capital, administration and general expense as well as all other items that should comprise a complete cost estimate. Further details regarding any items of cost may be had from the authors.

Templeton *(1)*, in 1947 mentions $65.00 a ton as the sale price of dried press cake alone. The value of dried press cake containing concentrate cannot be stated pending conclusion of current feeding tests with broilers and dogs. However, it is thus far apparent that the product in poultry rations is at least equal to wheat middlings. At $75 a ton for wheat middlings, the difference between cost to make and the value of the product is $41 a ton. Expressed as the cost of waste disposal this amounts to $10,780 a year or approximately three-quarters of a cent per case of tomato juice. In an area where dumping is no longer possible, a tomato processing plant may well be faced with a choice between going out of business or providing sewage disposal facilities. In such a situation the recovery procedures suggested here may represent the cheapest means of disposal.

## SUMMARY AND CONCLUSIONS

It is well established that the disposal of tomato processing wastes is a serious problem in certain areas.

Some plants now recover part of the waste in the form of dry press cake, and there has been a ready market in the east for this material when it is of good

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quality. A method is here described for producing a good product by drying press cake in a direct-fired, rotary alfalfa drier.

There is also described the development of a process whereby 83% of the total waste solids from a tomato juice or juice processing plant can be recovered. It consists in drying a mixture of dry press cake and concentrate made from the waste liquors. Feeding tests are now being made to establish its value as a feed supplement for broilers and dogs.

At an assumed value of $75 a ton for the product, the waste disposal cost would be $10,780 per year or about three quarters of a cent per case of tomato juice. This would probably be less than the cost to eliminate the wastes by sewage disposal.

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2. United States Department of Agriculture Agricultural Statistics 1951, page 265.

# The Control of "Off-Odor" Spoilage in Frozen Concentrated Orange Juice[a]

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**Lactic acid organisms isolated from off odor spoilage in frozen concentrated orange juice and capable of reproducing the spoilage are identified. Production controls against such spoilage are described, and media and methods for complementary laboratory control to check the effectiveness of production controls are suggested. Elimination of the problem may lie in flash heating and cooling of all evaporator feed juice in addition to presently practiced strict sanitary control measures.**

Spoilage characterized by a vinegary to buttermilk "off-odor" with an accompanying "off-flavor" was encountered by several packers of frozen concentrated orange juice during the 1949-50 season. There have been sporadic recurrences of this type of spoilage in the industry since the initial outbreaks. Concentrate having the off-odor of the spoilage is unmerchantable and frequently extensive production has been involved before discovery. Because of the considerable economic losses which resulted much effort has been expended and added production safeguards instituted to prevent the spoilage.

The isolation and identification of organisms from the initial spoilage outbreaks have been discussed by Hays *(7)*. During this investigation an orange serum agar was developed that was superior to Lindegren's agar for the isolation of spoilage organisms from concentrated orange juice. The direct microscopic examination of evaporator effluent was also found to be helpful in locating the foci of contamination. These foci were generally found in those stages of the high vacuum, low temperature evaporators where the lower concentrations are produced.

## GENERAL MORPHOLOGY OF SPOILAGE ORGANISMS

The great majority of organisms isolated from the 1949-50 spoilage were Gram-positive, rod-shaped, lactic acid forming organisms capable of reproducing spoilage in 35° Brix evaporator effluent. Gum forming strains of cocci were also isolated but were unable to produce spoilage in the relatively high acid evaporator effluent characteristic of that season. However, from spoilage of frozen concentrated orange juice produced from the mid-season varieties of fruit during this season, the only cultures isolated have been cocci. The acidity of this fruit was lower than usual. Organisms isolated from this spoilage will readily reproduce typical "off-odor" spoilage in 20° Brix evaporator effluent of low acidity.

The observation that either lactobacilli or leuconostoc will be the predominant spoilage type, depending upon the acidity of the oranges being used, is similar to observations which have been made on the fermentation of sauerkraut. With this product, the initial fermentation is started by leuconostoc which later die off because of increasing acidity, whereupon organisms of the genus *Lactobacillus*, because of their greater resistance to acid, gain the ascendency *(5)*.

## MEDIA AND METHODS USED IN THE IDENTIFICATION OF SPOILAGE ORGANISMS

The fermentation of various carbohydrates useful in the identification of the spoilage organisms was determined by the use of a medium recommended by Pederson *(11)* having the following basic formula:

**Basic medium for identification of lactic acid organisms**

| | |
|---|---|
| Tryptone | 5 grams |
| Yeast extract | 2.5 grams |
| Tap water | 1000 ml. |
| Salt solution A | 5 ml. |
| Salt solution B | 5 ml. |

Salt solution A contains 10% each of $K_2HPO_4$ and $KH_2PO_4$

Salt solution B contains 4% $MgSO_4 \cdot 7H_2O$ and 0.2% each of $FeSO_4 \cdot 7H_2O$, $MnSO_4 \cdot 4H_2O$, and NaCl.

Sterile carbohydrate solutions were added to the sterile basic medium to give a final carbohydrate concentration of 1.5%. The acid produced by the fermentation of the various carboly-

[a] Presented at the Twelfth Annual Meeting of the IFT, Grand Rapids, Mich., June 11, 1952.

**TABLE 1**

**Cultural characteristics of frozen concentrated orange juice spoilage organisms**

| Cultural tests | *Lactobacillus plantarum, var. mobilis* | *Lactobacillus brevis* | *Leuconostoc mesenteroides* | *Leuconostoc dextranicum* |
|---|---|---|---|---|
| Gram stain | Positive | Positive | Positive | Positive |
| Morphology | Rods singly and in pairs | Rods singly and in pairs | Spheres usually in pairs | Spheres usually in pairs |
| Motility | Motile to 72 hours peritrichous flagella | Non-motile | Non-motile | Non-motile |
| Size of majority | 0.6-0.8 × 2.0-4.0 microns | 0.5-0.7 × 1.5-4.0 microns | 0.8-1.2 microns in diameter | 0.7-1.0 microns in diameter |
| Agar slant | Scant growth | Scant growth | Scant growth | Scant growth |
| Nutrient broth | Slight growth | Slight growth | Slight growth | Slight growth |
| Litmus milk | No change | No change | Acid (variable) | Acid (variable) |
| Surface colonies on orange serum agar | Circular, smooth, raised, maybe slimy | Circular, smooth, slightly raised | Circular, smooth, raised gum formation | Circular, smooth, raised usually gum formation |
| Nitrates | Not reduced | Not reduced | Not reduced | Not reduced |
| Gelatin | No liquefaction | No liquefaction | No liquefaction | No liquefaction |
| Indol | Not formed | Not formed | Not formed | Not formed |
| Hydrogen sulfide | Not produced | Not produced | Not produced | Not produced |
| Catalase | Not produced | Not produced | Not produced | Not produced |
| Orange serum broth containing NaCl | Growth at 5% | Growth at 5% | Growth at 5% | Growth at 7.5% |
| Orange serum broth containing Citric acid | Growth at 2.0-2.5% | Growth at 2.5% | Growth at 1% (variable) | Growth at 1% (variable) |
| Orange serum broth containing sucrose | Growth at 30-40% | Growth at 30% | Growth at 30% with gum formation | Growth at 30% usually with gum formation |
| Dextrose | Acid | Acid | Acid | Acid |
| Fructose | Acid | Acid | Acid | Acid |
| Sucrose | Acid | Acid | Acid | Acid |
| Lactose | Not fermented | Not fermented | Usually acid | Usually acid |
| Galactose | Acid | Acid | Acid | Acid |
| Maltose | Acid | Acid | Acid | Acid |
| Mannose | Acid | Not fermented | Acid | Usually acid |
| Arabinose | Acid | Acid | Acid | Not fermented |
| Xylose | ..... | ..... | Acid | Not fermented |
| Products of dextrose fermentation | Inactive lactic acid, trace of acetic acid | Inactive lactic acid, acetic acid $CO_2$ | Lactic acid, acetic acid $CO_2$ | Lactic acid, acetic acid $CO_2$ |
| Products of orange juice fermentation | Lactic acid, acetic acid $CO_2$ diacetyl | Lactic acid, acetic acid $CO_2$ diacetyl | Lactic acid, acetic acid $CO_2$ diacetyl | Lactic acid, acetic acid $CO_2$ diacetyl |
| Growth range | 4.4°-40° C. | 15°-40° C. | 4.4°-37° C. | 4.4°-37° C. |
| Optimum temperature | 30°-37° C. | 30°-37° C. | 20°-30° C. | 20°-30° C. |
| Oxygen relationship | Microaerophilic | Microaerophilic | Aerobic, facultative | Aerobic, facultative |

drates was determined by titration with 0.1*N*. NaOH and calculated as lactic acid.

The volatile and non-volatile acids produced by the fermentation of flasks of dextrose broth were separated by steam distillation and the non-volatile acids recovered from the residue by continuous ether extraction as recommended by the "Manual of Methods for Pure Culture Study of Bacteria" *(9)*. The acids were identified, and the optical activity of the lactic acid recovered was determined on its lithium salt. Additional lactic acid determinations were made by the colorimetric method of Baker and Summerson *(1)*.

## IDENTIFICATION OF ISOLATED ORGANISMS

The microscopic and cultural data used in the identification of the organisms isolated from "off-odor" concentrate are given in Table 1. The organisms were found to be *Lactobacillus plantarum* var. *mobilis*, *Lactobacillus brevis*, *Leuconostoc mesenteroides*, and *Leuconostoc dextranicum*.

Although Bergey's Manual *(4)* lists *Lactobacillus plantarum* as a non-motile organism, Harrison and Hansen *(6)* have described a motile variety of this species. The variety isolated by Harrison and Hansen fermented lactose while the concentrate variety does not ferment this sugar. Bergey's Manual recognizes non-lactose fermenting strains of *L. plantarum*.

The data presented in Table 2 cover the pH values and the percent acid, calculated as lactic, which is produced by the lactobacilli and leuconostoc under study by the fermentation of various carbohydrates.

## METHODS OF CONTROLLING "OFF-ODOR" SPOILAGE

As the fruit being used is, no doubt, the original source of spoilage organisms, its selection and inspection and the washing and sterilizing of the fruit surfaces are of prime importance in the control of "off-odor" spoilage. Extracted juice must be handled rapidly. Once the juice becomes contaminated with spoilage organisms, the evaporators may then become contaminated and spoilage results through the multiplication of the spoilage organisms in the citrus solids which are not being continually washed free from the surfaces of the evaporator by new product.

**Fruit selection, inspection, and washing.** Only a sound fruit of the desired maturity should be used in the preparation of a high quality product. Defective fruit must be eliminated before the fruit is stored in the receiving bins. If such fruit is not

**TABLE 2**

**Fermentation of carbohydrates by lactic acid organisms**

| Carbohydrate | *L. plantarum var. mobilis* | | *L. brevis* | |
|---|---|---|---|---|
| | pH | Acid calculated as lactic | pH | Acid calculated as lactic |
| | | % | | % |
| Dextrose | 3.4-3.6 | 1.2-1.4 | 3.7-3.8 | 0.7 |
| Fructose | 3.4-3.5 | 1.2-1.5 | 4.0-4.1 | 0.6-0.7 |
| Sucrose | 3.4 | 1.4-1.6 | 3.8 | 0.6-0.8 |
| Galactose | 3.4-3.5 | 1.0-1.1 | 3.7-4.1 | 0.4-0.7 |
| Lactose | 6.8 | 0.08 | 6.8 | 0.08 |
| Maltose | 3.4 | 1.2-1.3 | 3.8 | 0.6-0.9 |
| Mannose | 3.8 | 0.6 | 6.8 | 0.08 |
| Arabinose | 4.2-4.3 | 0.3-0.4 | 4.5 | 0.3 |
| Control | 6.8 | 0.08 | 6.8 | 0.08 |

| Carbohydrate | *Leuconstoc mesenteroides* | | *Leuconstoc dextranicum* | |
|---|---|---|---|---|
| | pH | Acid calculated as lactic | pH | Acid calculated as lactic |
| | | % | | % |
| Dextrose | 4.0-4.1 | 0.4-0.5 | 4.0-4.1 | 0.4 |
| Fructose | 3.8 | 0.6-0.7 | 3.7-4.0 | 0.6-0.76 |
| Sucrose | 4.0-3.8 | 0.4-0.7 | 4.0-4.1 | 0.4-0.65 |
| Galactose | 4.2-4.3 | 0.3-0.34 | 4.3-4.4 | 0.3-0.5 |
| Lactose | 6.8-4.2 | 0.05-0.4 | 6.9-4.5 | 0.05-0.25 |
| Maltose | 4.0 | 0.4-0.5 | 4.5-4.1 | 0.2-0.4 |
| Mannose | 4.1 | 0.4-0.5 | 6.9-4.3 | 0.05-0.4 |
| Arabinose | 3.9-4.0 | 0.4-0.7 | 6.9 | 0.05 |
| Control | 6.9 | 0.05 | 6.9 | 0.05 |

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removed, the surfaces of sound fruit in the bins may become heavily contaminated or the bins may become infected so that the surfaces of fruit from successive loads may become contaminated and make the fruit surface sterilization more difficult.

The importance of final fruit inspection cannot be overemphasized. Beisel *(2)* and Wolford and Berry *(13)* report that juice extracted from defective fruit had many times higher count than juice extracted from normal fruit. During the 1949-50 season, juice extracted aseptically from fruit, which by casual inspection appeared normal, had a bacterial population ranging from 3,000,000 to 8 000,000 organisms per ml. of juice. On closer inspection, spots slightly more orange colored than normal could be observed on the peel; such spots were soft and the interior of these oranges a mass of deteriorated pulp.

After defective fruit has been removed, it is essential that the surfaces of the fruit going to the extractors be washed and sanitized effectively as the residual microbial load on the fruit surfaces will play an important role in the count of juice to be extracted.

Rinse tests should be made to determine the microbial load of the fruit surfaces before and after washing in order to check the efficiency of the washing and sanitizing procedure. Beisel *(2)* has written in detail on the use of detergents in conjunction with soak tanks, high pressure sprays, and brush washers in preparing the fruit so that the surface of the fruit can be sanitized. Quarternary ammonium compounds as well as chlorine are used in the industry for sanitizing agents. The washing and sterilizing of fruit can be wasted effort if the belts conveying fruit to the size graders and extractors are insanitary.

**General plant sanitation.** Germicidal sprays or baths should be installed on conveyor belts and elevators to keep these pieces of equipment in a satisfactory condition. In addition, this equipment should be cleaned and sanitized at regular intervals, the frequency of which is established by the results of swab tests and visual inspection.

Extractors, juice troughs, finishers, and juice holding tanks should be cleaned frequently. Many plants have found it advisable to clean such equipment at 4 to 8 hour intervals. Duplicate equipment installations facilitate maintaining such a program. The use of alkaline detergents is helpful in such clean-up as the hesperidin deposited by the citrus juice is soluble only in alkaline solutions.

Blending tanks and filler bowls should also be cleaned and sterilized, the schedule to be determined by cultural results. In all probability this equipment will not need cleaning as often as the equipment in contact with single strength juice.

**Evaporator design and clean-up.** Since evaporators have been identified as harboring the main foci of "off-odor" spoilage contamination, considerable attention should be given to the design of such equipment. The evaporators should be so constructed that the soluble solids entrained by the effluent vapors are minimized in amount, given the least opportunity to collect on unflushed surfaces, and prevented from return to the body of the concentrating liquid. An accumulation of static citrus solids in an evaporator supplies the nutrients for the spoilage organisms. This spoiled material may later drop into or be flushed by circulation or ebulition into the body of the concentrate.

Most of the evaporator surfaces may be cleaned and sanitized by the recirculation of alkaline detergents and sanitizing solutions, but headers, domes of tube nests, etc. cannot be cleaned thoroughly by this method. It is essential that the evaporators be opened and all parts not cleaned by recirculation of solutions be scrubbed with brushes and/or cleaned with high pressure equipment.

The condensers should also be sanitized so that the potential contamination of an evaporator by "kick-backs," momentary drops in vacuum which sometimes occur during operations, will be minimized.

**Laboratory control.** Since management must depend upon the laboratory to determine the operating time between clean-ups and to assay the effectiveness of the clean-up program so that a quality product may be produced at all times, the laboratory should also have jurisdiction over the fruit accepted for use. The most precise laboratory methods are futile if the results are not applied.

Hill and Faville *(8)* and Beisel *(3)* have indicated the desirability of using a two-medium system in the bacteriological control of frozen concentrated orange juice, one medium to be used in checking on general plant sanitation, the other medium to be used to determine the concentration of potential spoilage organisms. Media which are apparently suitable for this purpose have been developed and are being utilized in the industry.

As has previously been shown *(7)* tomato serum agar was used in the original isolation of the "off-flavor" spoilage organisms, and Metcalf, Hucker, and Carpenter *(10)* had demonstrated that both tomato juice and orange juice possessed lactobacilli growth stimulating factors. Since the spoilage organisms grew so readily in orange juice, the authors suggested the substitution of orange serum for tomato serum in the agar medium to be used in the detection of these acid forming organisms as well as other organisms capable of growth in orange juice. Work at this laboratory showed that this medium supported the growth of these organisms even better than tomato serum agar, so orange serum agar was proposed to the industry for use as a routine medium for culturing product samples.

Laboratory studies have indicated that orange serum agar is most productive at a pH about 5.5 so far as the growth of spoilage organisms is concerned. Typical data are shown below.

**Millions of organisms recovered per ml. of juice inoculated with L. plantarum var. mobilis**

| Sample No. | pH of medium | | | |
|---|---|---|---|---|
| | 6.5 | 6.0 | 5.5 | 5.0 |
| 1 | 67 | 123 | 135 | 99 |
| 2 | ....[b] | 125 | 140 | 117 |
| 3 | ....[b] | 81 | 92 | 84 |
| 4 | ....[b] | 129 | 139 | 146 |

[b] Colonies too small to count with accuracy.

Orange serum agar having the following formula as originated by the authors has been widely accepted as a control medium by the industry:

**Orange serum agar**

| | |
|---|---|
| Tryptone | 10 g. |
| Yeast extract | 3 g. |
| Dextrose | 4 g. |
| Dipotassium phosphate | 2 to 3 g.[c] |
| Agar | 17 g. |
| Orange serum | 200 ml. |
| Distilled water | 800 ml. |

[c] The amount of phosphate to be used will depend upon the buffering capacity of the juice from which the serum is prepared. The final pH of the medium after sterilization for 15 minutes at 250° F. (121° C.) should be about 5.5.

A valuable adjunct to orange serum agar in the control of spoilage would be a medium in which spoilage organisms would be readily identifiable. Beisel *(3)* has suggested McCloskey's Sucrose Agar for this role. Members of the genus *Leuconostoc* grow readily in this medium.

Vaughn and Emard *(12)* have suggested the addition of sorbic acid to liver infusion agar for the isolation or enumeration of catalase negative organisms. Laboratory data indicate that orange serum agar, containing 0.13% sorbic acid, is superior to liver infusion-sorbic acid medium for the enumeration of lactic acid organisms in citrus products. In the preparation of the orange serum-sorbic acid medium, the dipotassium phosphate is omitted from the general formula and the pH adjusted to 5.5 by the addition of sodium hydroxide.

Laboratory tests indicate that yeast, molds, and catalase positive organisms are inhibited by the sorbic acid medium. This medium has been tried by several laboratories in the industry this past season and appears to afford a reasonable means for estimating the level of spoilage types of organisms.

Although media have been developed in which spoilage organisms may be detected readily, cultural results are not available until after 48 hours of incubation. In case the inspection

system fails to eliminate defective fruit or the clean-up crew does not clean and sanitize the system thoroughly, spoilage might develop before the control plates have been examined. A running check can be maintained on the current production by the use of the microscope. The high sugar concentration of evaporator effluent makes it difficult to examine microscopically, but it can be done.

A very acceptable method for preparing smears of evaporation effluent for microscopic examination is a modification of North's Methylene Blue Milk Stain. There is probably even less correlation between the direct count and plate count of evaporator effluent than there is when milk is examined by the two methods. Even with these limitations, the direct microscopic method has proved to be a very useful tool in following the microbial load of evaporators. Under normal operating conditions, very few organisms are observed in evaporator effluent, while a rather sudden and continued increase in organisms should serve as a warning of potential spoilage.

Preliminary trials have indicated that the phase contrast microscope might well be adopted for use in the control laboratory. Microorganisms are readily detected in unstained slides of evaporator effluent or finished concentrate.

In this paper the bacterial spoilage occurring in frozen concentrated orange juice has been referred to as "off-odor" spoilage. This stems from the fact that although the bacterial action does produce an "off-flavor," the spoilage may be detected more readily by the odor produced. If "off-odor" concentrate has been produced, it should be possible to detect it in the laboratory before the produce is shipped from the plant. The odoriferous constituents of the spoilage are quite volatile, and are consequently more easily detected in a warm product. The smelling of warmed concentrate samples should be a compulsory routine test in the control laboratory.

## DISCUSSION

In the preparation of high quality concentrate there can be no substitute for sound fruit, and the plant must be maintained in a sanitary condition. All plants producing frozen concentrated orange juice operate on this principle, yet spoilage has occurred. The authors have felt for several years that the ultimate solution of the evaporator spoilage problem lies in the rapid heating and cooling of the juice immediately before the evaporator to destroy all spoilage organisms. The most heat resistant spoilage organisms isolated to date have been destroyed when heated for 10 seconds at 160° F. (71° C.) in orange juice pH 3.9. Pilot plant studies and commercial application have shown that the proper application of heat has no commercially significant effect upon the flavor of the concentrate.

The "cut-back" juice need not be heated. Volatile flavor constituents are restored to the concentrate by the addition of raw "cut-back" juice, whether or not the evaporator feed juice has been heated. The fruit must still be carefully selected and a meticulous sanitation program must still be maintained, even though the use of heat introduces a large safety factor.

## SUMMARY

Lactic acid organisms isolated from "off-odor" spoilage in frozen concentrated orange juice and capable of reproducing the spoilage have been identified as *Lactobacillus plantarum* var. *mobilis*, *Lactobacillus brevis*, *Leuconostoc mesenteroides*, and *Leuconostoc dextranicum*. It has been observed that lactobacilli are the predominate spoilage type in high acid juice while the less acid tolerant leuconostoc will probably be more numerous in lower acid juice.

Organisms of these types present in the raw juice are able to multiply in the evaporators during those stages which produce the lower concentrations and the spoilage has been found to occur principally during the early stages of evaporation. Production controls against the spoilage require minimizing the numbers of the causative organisms in the juice fed to the evaporator by careful fruit inspection to eliminate unsound oranges, thorough washing and sanitizing of the fruit surfaces before juice extraction, and scheduled, thorough cleaning of all juice extraction and handling units at frequent intervals. Equally important is evaporator equipment designed to minimize collection of citrus solids on surfaces not flushed by the evaporator action, and frequent shut-downs to permit complete cleaning of the evaporators and sanitizing of the condensers.

Complementary laboratory control should be used to check the effectiveness of the production control measures and to time the frequency of the clean-ups to the fruit condition and equipment set-up. Media and methods are suggested for determining the load of spoilage organisms in juice and evaporator effluent, and for direct microscopic estimation of the microbial condition of the product at the time of production. Odor tests on warmed concentrate should also be routine to furnish an added early sign of potential danger.

Although producers have instituted meticulous sanitary control procedure, outbreaks of the spoilage are still encountered. It is suggested that the ultimate elimination of the evaporator spoilage problem may lie in the flash heating and cooling of all evaporator feed juice. Careful fruit selection and sanitation of fruit and equipment are always essential to the production of high quality frozen concentrated orange juice. However, pilot plant trials and commercial application have demonstrated that flashing only the juice to be evaporated causes no significant flavor change and adds a tremendous safety factor against chance build-up of spoilage foci in the evaporators.

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# The Determination of a Satisfactory Type of Packaging for the Bulk Shipment of Dehydrated Apple Slices by Freight[a]

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**Several years ago, General Mills faced the problem of shipping hygroscopic, dehydrated apple slices in bulk from a California supplier to a plant in Chicago. In solving this problem, several packaging possibilities were considered on the basis of performance and economics. Those practical were subjected to laboratory examination. The examination resulted in the selection of a water vapor barrier, a preliminary determination of the necessary container strength and size, and a method of closing the container. A cross-country shipping test was set up to verify the laboratory findings. Results of this test led to packaging recommendations that were used in the satisfactory handling of four million pounds of dehydrated apple slices.**

In 1946, General Mills faced the problem of shipping dehydrated apple slices in bulk from a supplier in California to a plant in Chicago. The slices were extremely hygroscopic; at all times, they required unusually effective protection from water vapor.

This paper deals with the solution of that problem. It discusses: 1, the packaging possibilities considered; 2, the preliminary laboratory examination of the feasibility of these possibilities; 3, an experimental check under shipping conditions approaching actual use; and 4, commercial confirmation.

Apple slices had previously been supplied to the Armed Forces in 5-gallon square tins sealed with a friction-type cover. Objections to this container were its high cost, its small size (which meant it required a great deal of handling), and the freight problem involved in its re-use.

An economic survey was made to find the most promising of the suggested packaging possibilities from a cost standpoint. The suggestions included fiber drums with moisture protection, two weights of metal drums, tank cars, multiwall bags, and corrugated containers with moisture protection.

Metal drums had the same high cost and re-use problems as the 5-gallon tins. In addition, they were not available at the time.

Nested fiber drums were reasonable in cost; since they could be nested for return shipment, they appeared to be a promising solution. But they, too, became unavailable.

In addition to presenting a storage problem at the plant, tank cars were not considered acceptable because of the hazard of crushing the apple slices at the bottom.

Although multiwall bags were available and cheap, they were not a solution to the problem. They offered the apple slices no protection against crushing during stacking, which would be necessary both during shipment and during storage in the Chicago plant. Another serious drawback was the likelihood of attrition and puncturing of the bags during shipment. If the puncturing were due to wood splinters, there would be both loss of the moisture protection necessary to preservation of good quality in the slices and possible contamination of the product by the splinter.

Thus there remained only one possibility, corrugated containers. Corrugated containers had three immediate advantages: they were inexpensive, they were available, and they could be readily knocked down and shipped back to California in bundles. It was necessary to provide them with adequate moisture protection and to evaluate them for handling, shipping, and stacking characteristics.

Since adequate moisture protection was the major problem in determining whether this type of container could be used, it was necessary to make an assumption in order to proceed with the problem. This asumption was that the time necessary for transportation between Chicago and California together with the time the apple slices would be on hand at the Chicago plant before being repackaged would not exceed one month. Considering this time factor and the fact that the slices were produced at 2.0% moisture and had to be repackaged into consumer packages at not more than 2.5% moisture, it followed that the slices ought not be allowed to gain more than 0.5% in weight during one month of shipment and storage. For experimental purposes, these conditions were approximated by express shipment from Minneapolis to Chicago and return plus 4 weeks of storage in the Weather Room, a storage facility in the laboratory which operates in a cycle with average conditions of 65% relative humidity and 82.5° F. (28° C.). A search was started for a moisture vapor barrier, a bag material which might be used in corrugated containers to protect the slices. The moisture vapor permeability of the bag material under consideration had to be capable of limiting the total weight gain of the slices within the amount allowed.

That this was a difficult problem is illustrated by the moisture equilibrium curve of apple slices (Figure 1) which shows that apple slices at 2.0% moisture are in equilibrium with an atmosphere of 10% relative humidity.

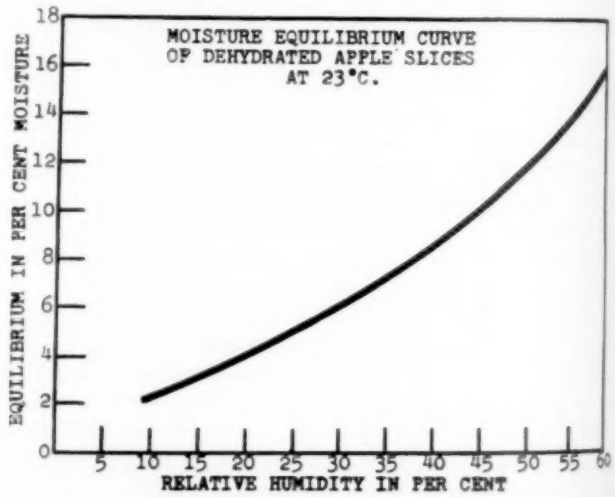


**Figure 1. Moisture equilibrium curve of apple slices. Apple slices at 2.0% moisture are in equilibrium with an atmosphere of 10% relative humidity.**

The necessary minimum moisture vapor permeability for the barrier material was determined from the following formula:

$$P = (0.005W)/(AT)$$

where $P$ is the minimum moisture vapor permeability; $W$, the total weight of slices originally in the container; 0.005, the permitted weight gain per unit weight of slices; $A$, the area of the barrier (comparable to the area of the container); and $T$, the time in months. This value expressed in metric units turned out to be 1.60 g. per square meter per 24 hours at Weather

[a] Presented at the Twelfth Annual Meeting of the IFT, Grand Rapids, Mich., June 9, 1952.

Room conditions. At the conditions under which the cabinet in which we determine water vapor permeability values operates, namely 72° F. (22° C.) and 65% relative humidity, this value becomes 1.13 g. per square meter per 24 hours. Papers having flat permeabilities above this value were eliminated without further experimental work.

The moisture vapor permeability results of some of the barriers considered are shown in Table 1. Most of the flat permeability results shown are better than the set limit of 1.13 g. per square meter per 24 hours. The barrier used in the shipment of dried vegetable mix is included in this list because it was used later to show that the permeability standards had not been set too high.

**TABLE 1**

**Moisture vapor permeability results of some possible bulk apple slices bag materials**

| No. | Description | Moisture vapor permeability, g. per square meter per 24 hours at 72° F. and 65% R.H. | |
|---|---|---|---|
| | | *Flat* | *Fold* |
| 1 | Kraft laminated to foil, heat sealing lacquer coated on foil side. Total ream weight 49 pounds. | 0.15 | 0.10 |
| 2 | Kraft laminated to sulfite, heat sealing lacquer coated on sulfite side. Total ream weight 81 pounds. | 0.61 | 1.7 |
| 3 | Laminated cellophane, MSAT, 600. | 0.53 | 0.84 |
| 4 | Kraft laminated to highly calendered sulfite, heat sealing lacquer coated on sulfite side. Total ream weight 71 pounds. | 2.0 | 4.7 |
| 5 | Paper wax laminated to foil wax laminated to tissue. Total ream weight 80 pounds. | 0.042 | 1.0 |
| 6 | Waxed paper from a bag used for dehydrated vegetable mixes. Total ream weight 51 pounds. | 3.0 | 6.8 |

Next, storage tests were set up in the Weather Room to determine whether potential packaging materials actually would protect the slices within the specified limit. The filled containers making up each test were first shipped by Railway Express to Chicago and back. This was to eliminate unusually good results made possible by lack of handling. The results from a representative storage test in the Weather Room are given in Table 2. The liner bags used in this test were shaped over a mandrel, inserted into corrugated shipping containers of 200-pound test board, filled with 25 pounds of apple slices, and closed by heat sealing. The containers measured 20¼ inches × 15⅜ inches × 16⅞ inches and are normally used to ship 36 packages of 8-ounce cereals. They will be referred to throughout this paper as cereal size cases. The filled containers underwent the usual express shipment before storage.

The two best performers were the kraft laminated sulfite (No. 2) and the laminated cellophane bags (No. 3). Flat permeability results are included for comparison. They show that the kraft to calendered sulfite lamination (No. 4), which has sub-standard permeability values, did not perform well. However, the kraft to foil combination (No. 1),[c] which was within the permeability limit, also failed to perform well. A discrepancy such as this can be due to failure to seal

[c] This was made of spliced material, since foil laminations of the required width were not available.

**TABLE 2**

**Data obtained on apple slices bags in a weather room storage test**

| No. | Description | Moisture gain after 4 weeks[b] | Flat moisture vapor permeability (65% R.H., 72° F.) |
|---|---|---|---|
| | | % | *g. per square meter per 24 hours* |
| 1 | Kraft laminated to foil, heat sealing laquer coated on foil side. Total ream weight 49 pounds. | 0.7 | 0.15 |
| 2 | Kraft laminated to sulfite, heat sealing lacquer coated on sulfite side. Total ream weight 81 pounds. | 0.3 | 0.61 |
| 3 | Laminated cellophane, MSAT, 600. | 0.3 | 0.53 |
| 4 | Kraft laminated to highly calendered sulfiite, heat sealing lacquer coated on sulfite side. Total ream weight 71 pounds. | 0.7 | 2.0 |
| 5 | Paper wax laminated to foil wax laminated to tissue. Total ream weight 80 pounds. | 0.5 | 0.042 |

[b] Weather Room storage of 65% relative humidity and 82.5° F.

properly, to bad fracturing during bag fabrication, or to crumpling or wrinkling of the bag material during shipping or storage. Obviously, it was necessary to check performance by actual use. At this point, it was apparent that adequate barrier materials for this purpose were available.

Another facet of the problem, that of container strength, was simultaneously under consideration.

Inspections of the cases of 200-pound test board which were used in these tests revealed that frequently they returned from shipment battered and not re-usable. An additional shipment of cereal size cases, some of which had perimeter inserts, was made to Chicago. When they returned, cases constructed of 200-pound test board with no inserts showed severe damage; the board structures were broken and a corner of one taped seam was split. These cases were probably not re-usable. All the cases constructed of 200-pound test board having a 200-pound test board perimeter insert returned in re-usable condition.

In addition to the Railway Express shipments, containers were tested in compression testing equipment. These tests confirmed the information obtained in the shipping test that 200-pound test containers were appreciably weaker than the same containers containing inserts. But handling of inserts was time consuming, and the additional strength in stacking was obtained only when the container was in an upright position. These results and considerations indicated the need for a container without inserts made of test board stronger than 200 pounds.

After several trials with adhesives and with kraft tapes, it was tentatively decided that tape was the best method of closing the container flaps. It greatly facilitated knocking down the containers for the return shipment.

From the preliminary work on the corrugated container, the weight of board to be used, the tape method of closing the container, and the type of moisture protection required was relatively well established. There

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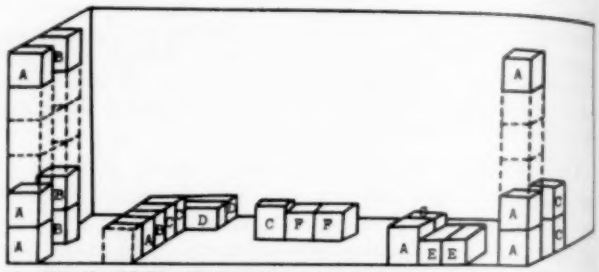
remained the problem of finding out whether this experience would be confirmed by simulated conditions of use.

For this reason, a shipping test between Buffalo, New York, and Los Angeles, California, was inaugurated; it included as variables the types of liners under consideration, the sizes of containers, the weights of container board, and the loading positions throughout the boxcar. Buffalo was chosen for the origin of the shipment because the materials could be included in a carload of company material shipped from the Buffalo plant.

The 24 cases for this bulk shipment of apple slices were assembled at Minneapolis at General Mills Research Laboratories and were shipped to Buffalo by truck. At Buffalo they were loaded into a 50-foot boxcar in predetermined positions. The remainder of the boxcar was filled with other cased products. The positions used were designed to sample as many as possible of the loading conditions in the boxcar. Since this car contained quite a number of different sized cases, loads were not always borne as they would have been in a car loaded with uniform cases.

The positions of cases containing dehydrated apple slices are shown in Figure 2. The letter A indicates a cereal size case of 200-pound test board. The letter B indicates the same size case made of 275-pound test board. The letter C again indicates the same size case, this time of 200-pound test board but fitted with a perimeter insert of 200-pound test board. Cases lettered A, B, and C were fitted with disposable bags of kraft laminated to sulfite. Bags made of this material were shown to be adequate moisture vapor barriers in the Chicago express shipment and storage test, the results of which were shown in Table 1.

Letters D and E indicate cases of the dimensions 12 inches × 12 inches × 34 inches. They were not considered to be so practical in size as the cereal case and were included in the test only because of the possibility that foil laminated inner liner bags would be used. (At that time commercial bags made of foil laminations were limited to the size used in this container by the maximum width of foil rolled.) Letter D indicates that the case was made of 200-pound test board, letter E that it was made of 275-pound test board. The bag used in each case was again made of kraft laminated to sulfite.




A 200 lb. BOARD, KRAFT-SULFITE BAG LINER
B 275 lb. BOARD, KRAFT-SULFITE BAG LINER
C 200 lb. BOARD AND INSERT, KRAFT-SULFITE BAG LINER
D 12" x 12" x 34", 200 lb. BOARD, KRAFT-SULFITE BAG LINER
E 12" x 12" x 34", 275 lb. BOARD, KRAFT-SULFITE BAG LINER
F 17" x 17" x 17", 275 lb. BOARD, DEHYDRATED VEGETABLE MIX BAG

(NOT DRAWN TO SCALE)

**Figure 2. Boxcar positions of cases containing dehydrated apple slices. A, B, and C indicate, respectively, 200-pound board, 275-pound board, and 200-pound board plus insert, cereal size containers with kraft laminated to sulfite bags as liners. D and E indicate odd-sized containers of 200-pound and 275-pound board, respectively, with liner bags of the same material. F indicates a 275-pound cubic container with a waxed paper bag as liner.**

Letter F indicates a 17 inches × 17 inches × 17 inches cube of 275-pound test board with a waxed paper bag as a moisture vapor barrier; this combination was normally used in shipping a dried vegetable mix. The size of this container was determined by convenience; the container and the bag to fit it were readily available. It was desired to include this particular bag because it was already in commercial use and because, with its poor flat permeability value of 3.0, it would show whether the moisture protection standards had been set too high.

Each container except the two letter F's contained 25 pounds of dehydrated apple slices. The letter F's contained 22.5 pounds. Two strips of 60-pound kraft tape were used to close each of these containers.

The loaded car was enroute from Buffalo, New York, to Los Angeles, California, between July 18th and July 27th or 28th. Figure 3 shows the route taken. Since the containers were loaded in Minneapolis during the last week of June,

**Figure 3. Boxcar shipping test route.**

shipped to Buffalo the third of July, shipped across the country to Los Angeles, and opened July 28th, they were exposed to a month of what were, from the standpoint of this packaging operation, severe weather conditions. It was felt, therefore, that if these containers and bags provided adequate protection under the conditions of this shipment, they would be satisfactory for use in the bulk shipment operation.

The unloading of the car took place in Los Angeles and the damage to each container was ascertained by inspection. The condition of some of the containers is illustrated in Figures 4 and 5.

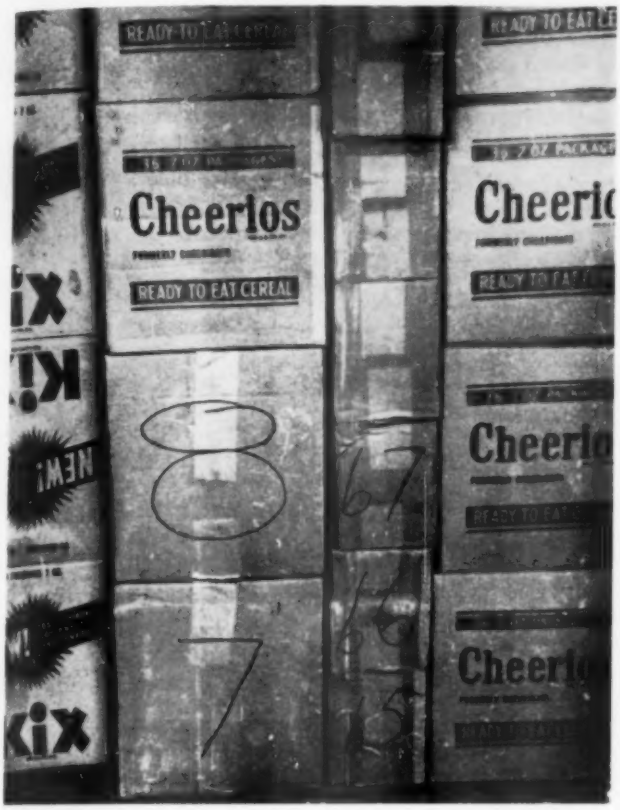



**Figure 4. Re-usable containers 7 and 8 from the bottom of a stack after shipment in the boxcar. These are cereal size containers of 275-pound test board.**

The containers marked 7 and 8 are the two bottom containers in a stack at one end of the car. They were made from 275-pound test board. Both were in good, re-usable condition.

Cases numbered 15, 16, and 17 were cereal size cases at the bottom of the load approximately over the wheels of the car. Case No. 15 illustrates how badly damaged a case made of 200-pound board can become at the bottom of a load. In contrast, Case No. 16 of 275-pound board and Case No. 17 of the 200-pound board with a perimeter insert, both of which are under the same load as Case No. 15, were relatively undamaged.

These pictured results were quite representative. Cases of 200-pound board containers of this size without inserts which were placed in the bottom two tiers of the load were in poor condition. All containers of this size made from 275-pound board were re-usable. All except one of the containers of the 200-pound board group with perimeter inserts were considered re-usable.

Cases 12 inches × 12 inches × 34 inches were not so good as the cereal size cases having the same weight board.

**Figure 5. Contrasting condition after boxcar shipment of cereal size cases of 200-pound board (No. 15), 275-pound board (No. 16), and 200-pound board with perimeter insert (No. 17). These three were at the bottom of adjacent stacks. Case No. 15 shows decided damage.**

The 17 inch × 17 inch × 17 inch cubes of 275-pound board were re-usable.

Some tape failure occurred, in spite of the fact that the 60-pound kraft tape was used double.

Moisture results were obtained on the apple slices in the various containers. This was important because the bags used had gone through what was assumed to be representative fabrication and more than usual handling and presumably, therefore, under these conditions would adequately cover results from conditions of actual use. These moisture gains are shown in Table 3.

**TABLE 3**
**Moisture gains of apple slices in shipping test**

| Description | Average moisture gain | Range of moisture gain |
|---|---|---|
| | % | % |
| Kraft laminated to sulfite bag fitting the cereal size case, pouch type bag with heat seal closure | 0.4 | 0.2-0.5 |
| Kraft laminated to sulfite bag fitting the 12 × 12 × 34 inch case, heat seal closure[a] | 1.0 | 0.8-1.2 |
| Waxed kraft bag used for shipping dried vegetable mix, double top fold closure | 2.5 | 2.4-2.5 |

[a] Open top seams were observed in these liners.

These results showed definitely that in the cereal size cases, the kraft laminated to sulfite bags were adequate moisture vapor barriers and that the waxed kraft vegetable mix bags were not.

On the basis of these findings, the decision was made to use cereal size containers of 275-pound test board sealed with one thickness of 90-pound kraft tape and containing kraft laminated to sulfite bags as moisture vapor barriers. Thus, the packaging recommendations for the commercial bulk shipment operation were determined.

These recommendations were used for commercial operation, and the shipment of apple slices between Oakland, California, and Chicago became routine. In 3½ years, more than four million pounds of the dehydrated apple slices were bulk shipped in this manner at a packaging cost of slightly over one cent per pound of slices.

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# Standard Methods vs. Pre-Asher Apparatus in the Pre-Ashing of Highly Foaming and Sugar Containing Products[a]

SILVIO CRESPO

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(Manuscript received May 19, 1952)

**Highly foaming and sugar containing products were pre-ashed by standard methods and by means of special pre-ashing apparatus. Results obtained by the two methods are reported and discussed.**

Ever since the ash content of food products became an important factor in food analysis, there has been very little change in the procedures used for ashing.

Most food laboratories have adopted the official method of the Association of Official Agricultural Chemists *(2)* for the ashing of their products. The brewing industry *(1)*, uses its own procedures for ashing beer, lupulin, etc., and the sugar industry uses either the official method of the A.O.A.C. or the conductometric method *(7)* for the ash determination in sugars, sirups, and molasses.

The merits of the above procedures are recognized by most analysts who have been using them. However, it is obvious that those methods have certain limitations that make them rather slow and cumbersome. This is especially true when pre-ashing highly foaming and sugar containing products. The fact is that these products have the tendency to foam over when they are heated from beneath. This phenomenon makes the pre-ashing operation very long and there is a possibility of losing the sample, if slightly overheated.

Aids have been found and reported *(3, 5, 6)* to ease the cumbersome and time consuming operation of pre-ashing products with foaming properties. Unfortunately, most of these aids have been passed to the silent files and no further comments have been made of their aiding effect. This was probably due to their impracticability when in use or perhaps they constituted a hindrance to the final ashing. The latter would be objectionable since the ashing of a product is not always done for the purpose of determining the amount of residue after combustion, but for a more extensive investigation to be performed on the residue.

Thus, recognizing the need for a faster and still dependable way of pre-ashing the type of products previously mentioned, an apparatus was developed *(4)*. This apparatus overcomes many of the limitations found in the standard methods. For example, the pre-ashing time is greatly reduced, highly foaming products behave considerably better; no special attention is required during the pre-ashing of samples.

## EXPERIMENTAL

**Samples and methods used.** To verify the usefulness of the pre-asher apparatus, samples of products obtained in the open market and others furnished by the Wahl-Henius Institute were tested by the available standard methods and the pre-asher apparatus. Most of the samples were run in duplicates. Some were pre-ashed as is and others were pre-ashed with an addition of diluted sulfuric acid. This was done to test the apparatus and sample behavior in both cases.

The tared dishes containing the samples were placed in the apparatus at a reasonable distance from the source of reflected heat. After the samples were carbonized, they were transferred to the muffle furnace and the ashing was completed at 500-550° C. All the dishes were covered with watch glasses before they were removed from the muffle and placed in a desiccator for cooling.

The samples pre-ashed by the standard methods, were treated according to their method recommendations. The final procedure for ashing was the same in all the methods used.

## RESULTS AND GENERAL DISCUSSION

The results obtained, as given in Table 1, showed a perfect agreement among the various methods.

Heating the samples from beneath caused some samples to foam quite high, while none of the samples pre-ashed in the apparatus presented severe cases of foaming, Figure 1.

The pre-asher apparatus performance was found very satisfactory. Its use in a control laboratory where a large number of samples must be ashed would represent a great saving of time with the assurance of dependable results.

**TABLE 1**
**Ash Determination**

| | Pre-Asher | | | Standard Methods | | |
|---|---|---|---|---|---|---|
| | 1 Ash | 2 Ash | Average | 1 Ash | 2 Ash | Average |
| | % | % | % | % | % | % |
| Molasses | 1.345 | 1.326 | 1.336 | 1.346 | 1.328 | 1.336 |
| Malt sirup | 1.230 | 1.228 | 1.229 | 1.229 | 1.231 | 1.230 |
| Corn sirup* | 0.290 | 0.291 | 0.290 | 0.296 | 0.303 | 0.299 |
| Beer high* | 0.187 | 0.188 | 0.188 | 0.188 | 0.194 | 0.191 |
| Beer light* | 0.159 | 0.159 | 0.159 | 0.159 | 0.159 | 0.159 |
| Lupulin | 8.33 | 8.33 | 8.33 | 8.33 | 8.33 | 8.33 |
| Cola beverage* | 0.0364 | 0.0342 | 0.0352 | 0.0352 | 0.0354 | 0.0353 |
| Salad dressing | 1.370 | 1.370 | 1.370 | 1.370 | 1.370 | 1.370 |
| Grape jam | 0.213 | 0.213 | 0.213 | 0.213 | 0.213 | 0.213 |
| Egg white | 0.734 | 0.684 | 0.704 | 0.617 | ..... | 0.617 |

* Sulfated Ash.

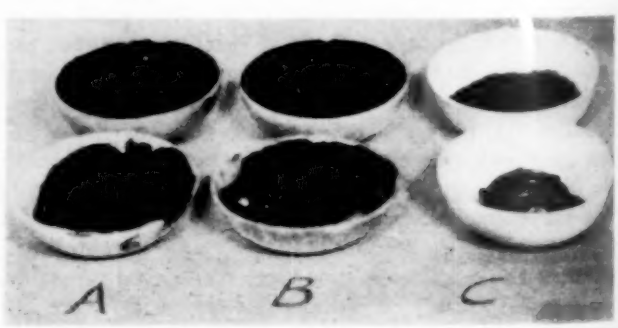


**Figure 1. Molasses and corn sirups pre-ashed. A and B, standard methods; C, pre-asher method.**

[a] Part of the study on the pre-asher apparatus was done at the American Institute of Baking, Chicago, Illinois.

The following are further advantages obtained by this method: the pre-ashing of products was done in half to three-fourths of the time required by the other method, any smoke expelled by the sample was burned before it escaped from the apparatus, the carbonization process was odorless and it required no special attention while in operation, and finally the apparatus could be built in any desired size to meet the laboratory requirement.

No samples were tested by the conductometric method due to the unavailability of the necessary equipment.


## SUMMARY

Comparative data were obtained in the ash determination of highly foaming and sugar containing products by using standard and pre-ash methods.

The results obtained by all methods were in perfect agreement. These results plus other advantages, have shown that the pre-asher apparatus is a dependable and time-saving device for laboratories where large amounts of samples must be ashed. The chief value of the apparatus is observed when highly foaming products are to be ashed.



## Acknowledgment

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# On Color in Tomato Products


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(Manuscript received March 20, 1952)


**Measurements have been made of changes in color of tomato juice as a function of processing treatment and of storage time and temperature. Comparisons of results with those of other laboratories (on a standard basis) show disagreement. Suggestions are made to overcome these difficulties.**


MacGillivray *(7)* studied the effect of processing temperature on tomato color in 1931. With temperatures ranging from 140° to 241° F. (60° to 116° C.), the pulp deteriorated steadily in color. He also observed that the temperature effect was independent of oxidative changes. Later *(8)* he made spectrophotometric and colorimetric analyses, and showed that the dominant wave length is a measure of desirable redness in tomatoes and by contrast, the relative brightness and purity are of less significance.

The trends observed by MacGillivray and by Robinson, Ransford, and Hand *(10)* are in general agreement with data obtained here on closely similar experiments. There are however disconcerting results when we attempt to compare the actual color measurements rather than the differences. This is of vital concern to the food industry when considering color specifications and marketing grades. A mass of data has been accumulated for tomatoes by Younkin *(12, 13)*, Robinson, Ransford, and Hand *(10)*, and Kramer *(6)* and agreement is necessary for orderly development of the subject.

**P.M.A. grades for tomato products.** Relevant portions of the specifications for puree (pulp), juice, paste, and catsup *(9)* are as follows: The score for the factor of color is determined by comparing the color of the product with that produced by spinning a combination of the following Munsell color discs:

| | | |
|---|---|---|
| Disc 1 | 5R 2.6/13 | glossy finish |
| 2 | 2.5YR 5/12 | glossy finish |
| 3 | N1 | glossy finish |
| 4 | N4 | mat finish |

A tomato product is graded fancy with respect to color when its color contains as much or more red than that produced by spinning the above mentioned discs in the following combinations: 65% of the area Disc 1, 21% of the area Disc 2; 14% of the area Disc 3 or Disc 4; or any combination of the two.

For standard grade, the percentages are as follows: 53% of the area Disc 1; 28% of the area Disc 2; 19% of the area Disc 3 or Disc 4; or any combination of the two.

The Munsell Color Company has supplied us with the following information on these four discs:

[a] Present address: Tel-Aviv, Israel.

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| Book notation | Tristimulus values | | |
|---|---|---|---|
| | *X* | *Y* | *Z* |
| 5R 2.6/13 | 1261 | 0759 | 0308 |
| 2.5YR 5/12 | 3231 | 2422 | 0690 |
| N1/ | 0128 | 0130 | 0161 |
| N4/ | 1145 | 1164 | 1404 |

In computing the tristimulus values for the combinations required for minimum standard and fancy grades, it is clear that a choice is allowed. If we allocate the whole of the 14% allowed for the neutral areas to N1 (black) the brightness will be at a minimum, whereas if it be allotted to the gray, N4, it will be at a maximum. We have calculated the tristimulus values three ways, to permit maximum, minimum, and an intermediate brightness (7% N1 and 7% N4, for fancy, and 9% N1 and 10% N4 for standard). Only the intermediate set of values is shown in detail.

| Fancy | *X* | *Y* | *Z* | Standard | *X* | *Y* | *Z* |
|---|---|---|---|---|---|---|---|
| 65% No. 1 | 0820 | 0493 | 0200 | 53% No. 1 | 0668 | 0402 | 0163 |
| 21% No. 2 | 0679 | 0509 | 0145 | 28% No. 2 | 0905 | 0678 | 0193 |
| 7% No. 3 | 0009 | 0009 | 0011 | 9% No. 3 | 0012 | 0012 | 0014 |
| 7% No. 4 | 0080 | 0081 | 0098 | 10% No. 4 | 0115 | 0116 | 0140 |
| Totals: | 1588 | 1092 | 0454 | | 1700 | 1208 | 0510 |

Hence we calculate the trichromatic coefficients and define the two colors. Below we include also values when *Y* is a minimum (N4/ = 0%), and when *Y* is a maximum (N1/ = 0%).

| Fancy | | | | Standard | | | |
|---|---|---|---|---|---|---|---|
| *Y* % | *x* | *y* | Dominant wave length | *Y* % | *x* | *y* | Dominant wave length |
| 10.2 | 0.5221 | 0.3513 | 600.5 | 11.1 | 0.5170 | 0.3577 | 598.5 |
| 10.9 | 0.5064 | 0.3486 | 601.0 | 12.1 | 0.4969 | 0.3535 | 598.5 |
| 11.65 | 0.4928 | 0.3462 | 601.0 | 13.0 | 0.4819 | 0.3503 | 598.7 |

The above data are calculated from tristimulus values provided by the Munsel Color Company from spectrophotometric curves with the specular component excluded. This is normal procedure apparently, in comparisons to be made with spinning discs under ordinary viewing conditions. Additional calculations were made, however, to designate the limits when the specular component was included, with maximum and minimum values for *Y*.

| Fancy | | | | Standard | | | |
|---|---|---|---|---|---|---|---|
| *Y* % | *x* | *y* | Dominant wave length | *Y* % | *x* | *y* | Dominant wave length |
| 12.3 | 0.4836 | 0.3454 | 601.0 | 13.1 | 0.4815 | 0.3511 | 598.5 |
| 13.3 | 0.4691 | 0.3428 | 600.5 | 14.5 | 0.4633 | 0.3471 | 598.7 |

The dominant wave lengths were obtained by reference to the chromaticity diagrams in Hardy's book *(2)*. It is clear that where the neutral gray is selected, and brightness is consequently at a maximum, the dominant wave length or hue is virtually unaffected. The effect is almost exclusively on the purity or chroma which is substantially lowered. The same results are to be observed when the specular component is included. It is customary to select the intermediate position, using both the gray N4/ and the black N1/, the percentages being 7% each for fancy and 10 and 9% respectively for standard. It seems clear from the text of the specifications for the tomato color grades that the hue is quite critically defined. The purity or chroma has been delimited more flexibly and varies somewhat with the brightness.

We have made calculations in terms of ICI quantities for samples listed in Table 1 of Robinson, Ransford, and Hand *(10)* by the use of equations developed for the Hunter Color-Difference Meter *(1)*. Thus:

$$L = 100\ Y^{1/2}$$
$$a_L = 175\ (1.02\ X - Y)/Y^{1/2}$$
$$b_L = 70\ (Y - 0.847\ Z)/Y^{1/2}$$

We include also six New Jersey samples taken from data presented by Younkin *(13)*. In the latter case, the values for $a_L$ and $b_L$ were read off the plot of his Figure 7, page 352. Substituting for $L$, $a_L$ and $b_L$, in the above equations we can solve for $X$, $Y$, and $Z$ and calculate $x$ and $y$. Results are as follows:

| | *Y* | *x* | *y* | Dominant wave length |
|---|---|---|---|---|
| New York varieties | | | | |
| Red Jacket 1 | 7.95 | 0.5075 | 0.3602 | 597.5 |
| 3 | 7.95 | 0.5074 | 0.3586 | 598 |
| 4 | 7.84 | 0.5073 | 0.3586 | 598 |
| 10 | 8.01 | 0.5081 | 0.3589 | 597.8 |
| John Baer 1 | 8.29 | 0.5080 | 0.3600 | 597.6 |
| 4 | 8.12 | 0.5093 | 0.3599 | 597.7 |
| 10 | 8.29 | 0.5111 | 0.3609 | 597.7 |

| | *L* | $a_L$ | $b_L$ | *Y* % | *x* | *y* | Dominant wave length |
|---|---|---|---|---|---|---|---|
| New Jersey samples | | | | | | | |
| 1 | 31.8 | 18.0 | 14.0 | 10.11 | 0.4743 | 0.3656 | 593.7 |
| 2 | 28.7 | 21.5 | 12.9 | 8.24 | 0.4960 | 0.3543 | 598.3 |
| 3 | 28.2 | 19.0 | 12.1 | 7.95 | 0.4824 | 0.3553 | 597.3 |
| 4 | 25.0 | 20.6 | 10.5 | 6.25 | 0.4948 | 0.3431 | 602.0 |
| 5 | 24.7 | 24.5 | 10.4 | 6.10 | 0.5109 | 0.3326 | 607 |
| 6 | 24.3 | 22.6 | 10.2 | 5.90 | 0.5048 | 0.3362 | 605.3 |

In Figure 1 we have plotted data as follows: cross-hatching, the general location of our own samples, except when overheated or stored at high temperatures; solid circles, the location of the fancy grade New Jersey samples; and open circles, the standard grade samples. (The designations fancy and standard refer to classifications US No. 1 and No. 2, respectively, in the text of that article).

As mentioned previously, we have re-calculated the ICI specifications for the Munsell discs with the specular component included. Proportionately the value of *X* increases the least, and of *Z* the most. The coefficient *x* consequently falls greatly from 0.500 to 0.46, and as *y* decreases somewhat, there is essentially no change in dominant wave length, though necessarily a loss in purity. Since the inclusion of the specular component does not change materially the hue, the general argument is unaffected.

## EXPERIMENTAL

In our experiments color was routinely determined by means of a three-filter Photovolt reflection meter. To avoid reflection errors, a special cell with a leucite window was placed on the inverted search unit of the Photovolt meter. The whole was covered with a black cloth. Measurements were reproducible and Munsell values could be computed within the errors reported

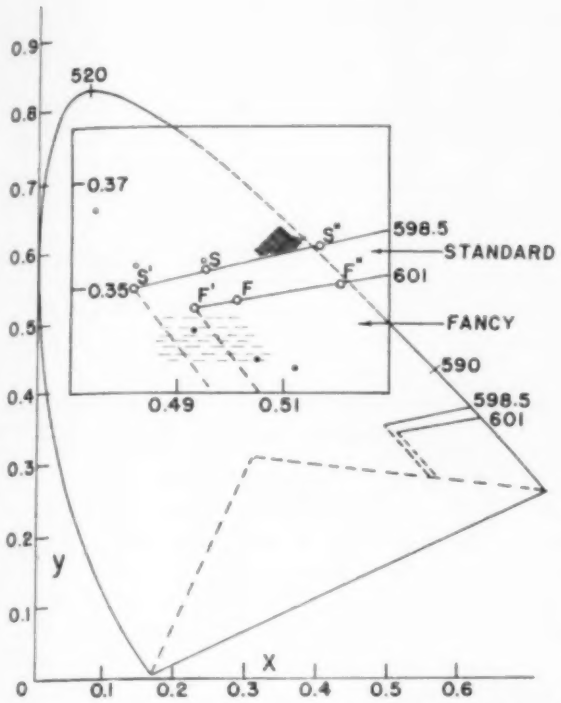


**Figure 1. Tomato color standards and the chromaticity diagram. Enlarged plot of area where tomato samples are located: Cross hatch, New York samples; open circles, New Jersey standard samples; closed circles, New Jersey fancy samples; and horizontal shading, present data; large circles, F F′ F″, S etc., fancy and standard grades at intermediate, maximum and minimum values, respectively, of Y.**

by Worthington, Cain, and Wiegand *(11)*. The discs and some samples were checked by reflectance measurements on a General Electric Recording Spectrophotometer,[b] and a few later samples were checked on the Beckman DU Spectrophotometer with a reflectance unit attachment, against a standard white $MgCO_3$ block, by use of a special leucite cell. Agreement is mediocre $\pm 0.003$ units of $x$ and $y$, which for the region of the color of tomato products means a difference of nearly 2 mμ in dominant wave length. It would clearly be of interest to have comparative data for a series of tomato products measured by different instruments.

### Preparation of Tomato Juice

The juice was prepared from clean halved tomatoes, preheated at 180° F. (82° C.) for 90 seconds. It was extracted in a Langenskamp laboratory pulper with a screen having 0.033 inch perforations. The juice was immediately deaerated at 28 inches of vacuum, filled into cans (211 × 314) and heated to 167° F. (75° C.) before sealing. Processing, with respect to time and temperature, headspace, and cooling were varied. A set was also prepared for storage at different temperatures.

Processing times at 185° F. (85° C.) were varied from 5 to 60 minutes. Temperatures were varied from 167° to 257° F. (75° to 125° C.) for 20 minutes. Headspace was varied from 0.3 to 6.0 ounces per 12-ounce can. Samples were cooled in running water through which air was bubbled, at 32° F. (0° C.) and at room temperature in air [79° F. (26° C.)]. Samples were stored at room temperature, 89°, 100° and 110° F. (32°, 37.8°, and 43.5° C.) and examined after 3, 7, 21, and 35 days.

## RESULTS

When our data are plotted (Figure 1, inset), they fall in the horizontally shaded area. The dominant wave length, 601-605 mμ, is correct for fancy grade, but the purity is lower than that of the disc combination *(9)*. The trend, as one deviates from sound processing practice or from normal storage conditions is to substandard hue, with decreased purity.

Samples stored at different temperatures deteriorated particularly in the hue component, or dominant wave length. Initially 605 mμ, it fell at 100° F. (37.8° C.) storage to 600 and 596 mμ after 21 and 35 days, respectively. The fall was more rapid at 110° F. (43.5° C.), 596 mμ after 21 days. At 32° F. (0° C.) there was no perceptible change from 605 mμ after 35 days.

High processing temperatures and long processing times showed similar trends. Results are plotted in Figures 2 and 3. The rate of cooling and volume of headspace also had a slight effect in the same direction.

The changes coincided with visual observation, with a change from bright red to a lighter red-orange, or even red-orange-brown. The extent of the change was however most pronounced in the storage series.

**Pigment changes.** It became of interest to confirm MacGillivray's finding *(7)* that color changes are largely independent of oxidative changes in the pigment. Therefore, 23 samples from the storage temperature series were analyzed spectrophotometrically for pigment content. First 5 g. of juice were extracted with acetone, the residue ground with sand in a small mortar and extracted with acetone and petroleum ether. The solution was then transferred to petroleum ether, dried, and made to volume (100 ml.) in the usual way. Optical densities were then measured at 502 mμ, to give essentially a measure of lycopene. The average value was 0.692, the range for the 23 samples extending from 0.670 to 0.709. Based on an absorption coefficient of 320 for lycopene, this indicates an approximate pigment content of 4.3 mg. per 100 g. of juice (approximately 6% solids). The absence of any significant loss (with normal headspace) substantiates Joslyn's statement *(4)* that there is apparently a change in state of the pigment. This is primarily a change from semi-crystalline aggregates to smaller aggregates and to solution in lipid globules.

## DISCUSSION

All previous workers stress the importance of hue, and minimize the effect of the other color components on the color grade of tomato products. This is reflected, for example in the plot of Younkin's data [Figure 7, *(13)*], where $L$ and $a_L$ vary over a substantial range. It is to be noted that the $a_L/b_L$ ratios for processed material from New York are much lower than those for many of the New Jersey samples. It is observed by Robinson, Ransford, and Hand *(10)*, that "the dominant wave length, and therefore $a/b$, is closely related to hue." The P.M.A. grading for color is indifferent to the variety, processing, or storage practice. It is concerned only with determining that a given sample does or does not meet a minimum requirement of redness for a particular grade. It is therefore pertinent to ask whether the $a/b$ ratio, dominant wave length as determined by different instruments, or any other measure of hue meets such a requirement. There is no disagree-

[b] By courtesy of Dr. C. H. Kunsman, Western Regional Research Laboratory, Albany, California.

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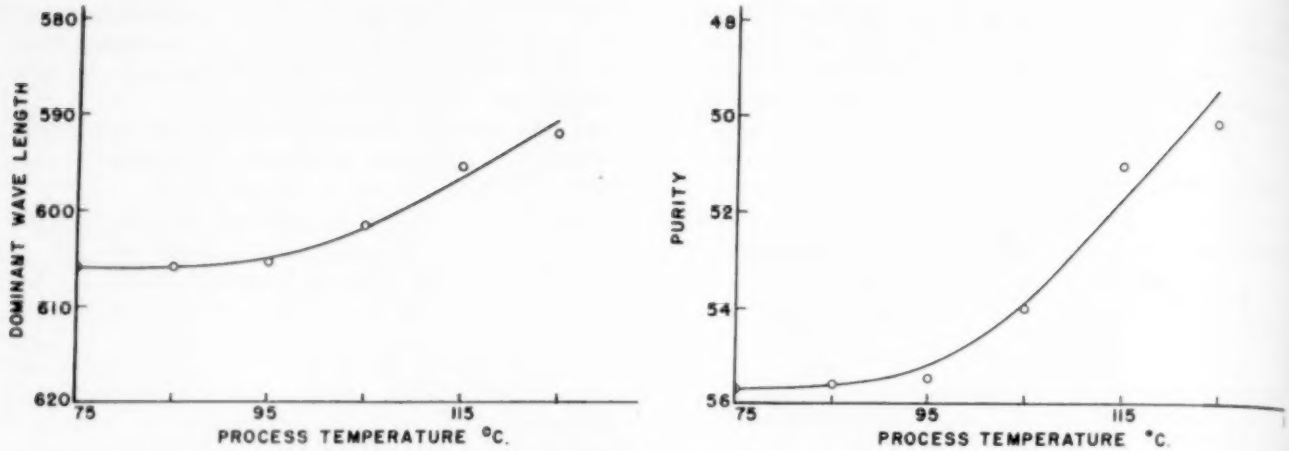


**Figure 2 Dominant wave length (left) and purity (right) as a function of process temperature.**

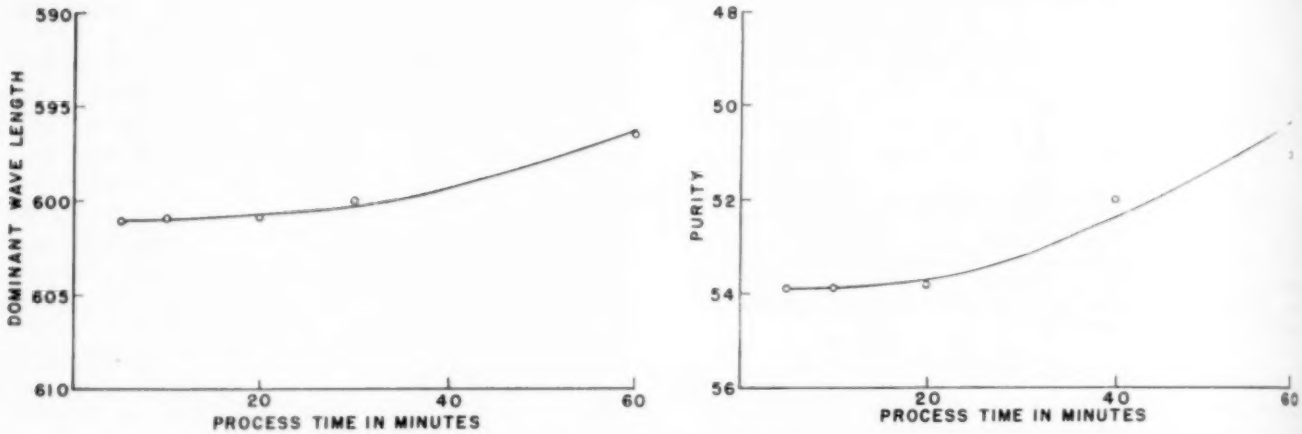


**Figure 3. Dominant wave length (left) and purity (right) as a function of process time.**

ment as to trends. It seems appropriate to point out that calibration against a single reference tile does not enable us, under existing experimental conditions, to fix the position of our unknown sample in color space. If three or four tiles were standardized, with perceptibility difference ranges to cover the areas delimiting fancy and standard grades, the situation would be greatly improved. If the tiles were calibrated by the Bureau of Standards, color differences might be accurately compared, regardless of differences in absolute values depending upon the instrument available in a particular laboratory.

Secondly, specifications for the official grades should be clarified. The hue has been critically defined in terms of Munsell and ICI standards by P.M.A. grades. This is not yet true in terms of $a_L$, $b_L$, or the $a_L/b_L$ ratios. Furthermore there must be a point at which purity or chroma is so low that the color is unacceptable, but this has not been defined.

An unknown tomato sample could be fixed and defined by reference to at least three standard tiles with predetermined perceptibility differences.

## SUMMARY

Measurements have been made of changes in the color of tomato juice as a function of processing treatment and of storage time and temperature. Trends are in agreement with data of other laboratories. A serious disagreement is shown when results are compared on a standard basis, and suggestions are made to overcome this difficulty.

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# Types of Food for Disaster Feeding[a]

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(Manuscript received June 17, 1952)

The importance of emergency feeding following a disaster scarcely needs emphasis. The prompt provision of some form of acceptable food and beverage after a disaster strikes is a most important measure, not only to allay hunger, but to prevent panic and to sustain morale. Experience has shown that if emergency feeding is instituted promptly after a disaster occurs, the injured and homeless are reassured that their community is still functioning and that someone will take care of them and their families. Under these circumstances they will begin to help themselves. It is only under these circumstances that communities can successfully resist disasters and get back on their feet, and, more important still under war conditions, into productive activity in the shortest possible time.

The need for special types of food for emergency feeding must be viewed in the light of current plans for the procurement of such food. The federally recommended plans as developed jointly by the Federal Civil Defense Administration and the Department of Agriculture have been presented in FCDA Policy Memorandum No. 10 and Advisory Bulletin No. 78. These are now in the hands of all major state and local civil defense units. Three points are especially pertinent to the topic of this paper. First, the FCDA recommended plan provides for the procurement of food from ordinary commercial channels. It follows that the types of foods made available will be those normally used and familiar to all. Secondly, FCDA has issued recommendations against general stockpiling of food for emergency feeding at this time. From this, it follows that there are, at this moment, no plans for the use of special types of dehydrated, concentrated, or specially preserved foods with special storage factors. Thirdly, FCDA has recommended that each family should maintain at all times a three-day supply of the foods normally used and familiar to the average housewife, and that these foods be rotated by constant use.

The above plan is tailored to fit the general situation as it now exists. It is evident that there are no pressing problems of food technology presented. However, the need for special types of food in emergency feeding must also be viewed, especially by food technologists, in the light of what may happen; that is, in the light of strategic situations which may develop. It is not too difficult to visualize circumstances and developments in the international situation which would necessitate radical changes in the present general recommendations as already described. Organized stockpiling might become necessary. Special packaged rations of various types might be required. Transportation may again become a limiting factor requiring reduction in bulk of many foods. Certain types of packaging materials might again become scarce. Food technology would become a critical factor in such a situation.

It is important that food technologists should take a long range view of the problems of food in civil defense. It is also evident that research designed to correct anticipated deficiencies must be started now. To wait until the emergency develops is too late.

The remainder of the discussion in this paper will be devoted to anticipated needs assuming the altered strategic situation outlined above and the adequacy of currently available food products in meeting this situation. The occurrence of such a strategic situation should not seem too remote to anyone who can remember our brief and rather mild exposure to such conditions in World War II. It should also be noted that changes in the methodology of warfare and the introduction of new types of weapons may alter our situation so that food products with special characteristics may be of far greater importance in future conflicts than in times past. This is especially pertinent in view of the developments of improved submarines, atomic bombs, guided missiles, and other weapons which could be used to disrupt transportation. In addition, the growing disparity between the world's population and the world's food supply will, in all likelihood, make food a truly critical item in any future conflict.

It is also important to remember that the need for special types of food will be governed to a considerable extent by the conditions under which they will be used. Two general types of disasters can be distinguished insofar as food technology is concerned.

One is the need for short-term feeding immediately following a disaster. In such a situation the injured and homeless must be fed and otherwise maintained until their normal living accommodations can be restored or until these individuals can be evacuated and relocated. Such disasters are not strangers in this country. Fire, floods, and windstorms have occurred frequently enough to provide considerable experience with this type of operation. In addition, one must anticipate the possibility of a surprise aerial or guided missile attack by some foreign power against one or more of our major cities. Under these circumstances emergency feeding would be required for short periods (probably no more than 7 days and in any event no more than 30 days) barring repeated attacks against the same target.

Second, a long-term emergency may persist throughout the duration of an international conflict and would affect not only food for emergency feeding, but the normal diet as well. While these two categories merge and overlap to a considerable extent, the remarks in this paper apply principally to the former category since this is primarily the responsibility of Civil Defense. It is recognized, of course, that Civil Defense may have to operate and would be responsible for short term emergency feeding, even in the second type of situation. However, the long term production of food and food products for main-

[a] Presented at the Twelfth Annual Meeting of the IFT, Grand Rapids, Mich., June 10, 1952.

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tainence of the civilian economy during a major conflict is the legal responsibility of Federal agencies other than FCDA.

The need for special types of food in emergency feeding will also be governed by the patients or peoples who will receive them. Special consideration must be given to foods for use in feeding and in the treatment of those with major injuries. Our medical authorities tell us that the prompt provision of high caloric, high protein, easily administered and assimilated food is a most important factor in recovery from conditions such as burns, fractures, injuries requiring major surgery, and perhaps even from radiation damage. Food for such patients often must be in a liquid form so that it can be consumed easily and can be given by stomach tube if necessary. Food products adaptable to such use will be described later.

Infants are unusually susceptible to even a temporary interruption in their supply of food. The provision of milk and milk products for this group must be given high priority. The normal flow of fluid milk will undoubtedly be interrupted following a disaster such as an atomic attack. It is not anticipated that the ultimate source of milk (the cow) will be affected by such disasters, nor is their milk likely to be contaminated by radioactivity. However, transportation will undoubtedly be difficult. Pasteurization and bottling plants will undoubtedly be disrupted and many may be destroyed. Consequently, alternate plans for obtaining milk must be considered.

The uninjured homeless must also be fed. For this group the provision of a hot beverage and some sort of food, preferably hot, is required. Food for this purpose must be easily prepared and served on a mass basis. It must have a high general acceptability. Detailed consideration of proteins, calories, vitamins, and minerals is not required when the probable period of emergency feeding is no more than 1 to 4 weeks. The primary purpose in feeding this group is to allay hunger, to maintain morale and the will to win.

When one examines the general types of food products which might be used to meet the needs outlined above, certain categories of food products assume unusual importance. Milk and milk products are outstanding in this regard. The availability of a milk preparation with low storage bulk and satisfactory stability in storage which can be reconstituted into an acceptable fluid milk, and which can be used for cooking and baking, would be most useful.

Dried milk could be a uniquely valuable food in emergency situations since it could be used to meet the peculiar food needs of infants, children, and other vulnerable groups. It can be added to fluid milk, or to water to provide high caloric, high protein fluids for injured patients. When properly packed it has a high degree of protection from radiological and other types of contamination. It has a relatively high caloric density in relation to its weight.

A completely satisfactory dried milk preparation remains to be developed. Whole, dried milk if gas-packed with an oxygen content below 3% has a fair keeping quality and a fair acceptance as reconstituted into fluid milk. However, the heat used in processing many of the currently available products gives a slight heated flavor and certain tactual qualities which detract from its value as fluid milk. In addition, its use is limited somewhat by rather slow and cumbersome reconstitution. Increased stability in storage is very desirable. Non-fat, dry milk solids have much better keeping qualities if dried to a moisture content of 4% and stored in a moisture-proof container. It is quite satisfactory for cooking purposes and for incorporation in high-protein drinks, and can be used for fluid milk. However, much of the non-fat milk solids customarily found in commercial channels has been processed with high-heat to give desired baking characteristics. These products would not be suitable for use as fluid milk. There are still some shortcomings in that fat and protein changes occur on prolonged storage with a tendency to a lower solubility. Adequate homogenization of the reconstituted product improves its palatability, but this would be difficult under emergency conditions. In addition, high calcium waters interfere with reconstitution of dried milk. Since much of the water supply under emergency conditions may come from secondary sources such as wells, this may be an appreciable problem. Dried milk, especially dry skim milk, has the additional advantage of being a product which is gaining increased popularity with the general public and would thus be a fairly familiar product to those who would use it in emergencies.

The second type of food product of importance in emergency feeding is dried eggs. Dried eggs, like dry milk, have a low storage bulk with a high nutritional value. They can be reconstituted into a familiar and liked food. They can be used like dry milk to make acceptable high protein high caloric drinks or for general cooking and baking purposes. The ordinary dried egg product, as now found in commercial channels, is not satisfactory for this purpose. One cannot be certain that these products are pasteurized and therefore free of Salmonella organisms. They would be dangerous unless used in recipes which provided for thorough cooking. Furthermore, these products are not satisfactory for making scrambled eggs after a short period in storage, although they are still satisfactory for certain cooking purposes. Tremendous advances have been made since World War II, however, in developing improved dried whole egg powders. The acidified, whole egg powder, prepared according to Army Quartermaster Corps specifications, is pasteurized before dehydration and consequently bacteriologically safe. It has a very acceptable stability in storage and can be used either for cooking purposes or for reconstitution into scrambled eggs. A second process employs fermentation to remove the small amount of sugar normally present in egg magma. This so-called "glucose-free whole egg powder" is now being produced commercially, although it has not found its way into the retail market. This product has a very satisfactory stability in storage, and can be used safely either for cooking and baking or for making scrambled eggs.

Bread is another item which is of basic importance in emergency feeding. Bread has been called the staff of life. While it is not quite that important in the average American diet today, experience has shown that the demand for bread increases under emergency conditions. Bread, itself, cannot be stored, although canned bread is a quite satisfactory product. The ingredients to make bread can be stored readily. Fortunately, some of our most important critical target areas are in a favorable position with respect to bread, in that most of their bakeries are located peripheral from the main probable center of attack. This is not universally true, of course. However, it does seem likely that the bread problem could be met by stockpiling the ingredients, rather than attempting to stockpile some type of bread product. Bread, cake, or roll premixes would be a very useful product under emergency conditions, in that a minimum preparation is required. Products with necessary stability in storage remain to be developed.

The provision of a hot drink immediately after a disaster is a most important morale measure. Experience in Great Britain during the last war demonstrated clearly that the first thing their people wanted after the bomb dropped was a cup of strong, hot tea. As a matter of fact, their emergency feeding groups went to considerable trouble to keep this tea at exactly 193° F. (89° C.). In this country it would be coffee instead of tea but the human reaction would probably be the same. In general, beverages seem to be in a very satisfactory state technologically. The availability of acceptable soluble coffees and tea, as well as cocoa, makes it likely that beverages will not constitute an appreciable problem. Canned fruit juices also occupy a somewhat unique position under emergency conditions, in that they can serve as a non-thirst provoking source of fluids should water temporarily be unavailable. In general, they

possess adequate stability in storage and a very high acceptability. They suffer from the disadvantage of occupying considerable storage space and of providing very few calories. Very promising developments are now occurring in the production of a stable and acceptable dried orange juice powder. This would overcome the problem of storage bulk, but would of course, have no value as a source of fluid. It would be, however, very valuable in prolonged emergencies as an easily transportable and easily stored source of vitamin C. Since the vitamin C requirement of the general population and even of infants, can be disregarded during an emergency of not more than 30 days, the provision of vitamin C is not a critical factor in short-term emergency feeding.

The traditional emergency meal consists of a soup or stew, along with a beverage and bread or crackers. For this purpose a dried, stable, and acceptable soup powder would be a very desirable item. Such a product might be used either alone, or if meat and other vegetables were available, a stew might be prepared using the soup powder as a base. A satisfactory product for this purpose has not yet been developed. Dried split pea soup is a very satisfactory item, but is not too good as a base for stews. Dehydrated vegetable soup mixes, thus far developed, tend to develop a hay flavor on storage. A dehydrated meat and vegetable stew base which requires only the addition of water and heat would be ideal for emergency feeding purposes. This product has not yet been developed.

Among the legumes, dried beans, split peas and lentils are very satisfactory products. However, they are difficult to cook without special processing. The canned or dehydrated cooked products would be superior for emergency use.

Fruits are desirable, although not essential products, for emergency feeding. Dried apple nuggets and rings, prunes, and raisins are excellent products for this purpose.

The production of a fully acceptable, dried or canned meat product has lagged considerably behind most of the items mentioned above. A fully satisfactory product has not yet been developed. Canned corn beef is quite stable in storage. The British have had canned corn beef in storage since 1944 and state that it is still edible. However, canned corn beef does not enjoy wide popularity in this country and has a limited use when mixed with other foods. Dried beef is a fairly acceptable product which is consumed normally to a limited extent in this country. However, when used as a frequent item in the diet, it becomes quite monotonous. The people of Berlin, during the Berlin blockade, after several weeks of dried beef almost completely refused to eat it. The Quartermaster Corps has developed a meat-food products bar which may be consumed as such, or which may be reconstituted. This product seems to have quite acceptable stability characteristics but its acceptability among civilian groups remains to be determined.

Considerable attention has been given to developing a single, all-purpose food item which could be distributed to individuals or which could be used in mass feeding operations, should the situation permit. Personally, I am pessimistic that such a product can be developed which will have the necessary acceptability characteristics, unless it is developed, produced, and finds acceptance in normal times so that the public can become familiar with it. In the words of Dr. Norman Wright of the British Ministry of Food, "a sudden emergency is no time for introducing untried novelties." It is not true that people who are hungry will eat anything. Experience has shown that people under stress, as they would be under the types of emergencies we must anticipate, tend to reject unfamiliar or disliked foods to a greater extent than they would under normal conditions. The provision of liked and familiar foods guarantees general acceptance and has a much greater morale effect. Building up a consumer demand for dehydrated products during peace time is the best way of insuring acceptance of similar products during an emergency. One must remember too, that public acceptance of dehydrated products can be discouraged quickly if inferior products are placed on the market. Much the same thing will occur eventually if the military forces are offered dehydrated or specially processed foods which have a very low acceptability. One needs only to remember some of the canned meat products of the last war to bring this fact home forceably.

In general, the present focus in the dehydration industry seems to be on producing a dehydrated product, which on reconstitution becomes indistinguishable from the parent material, and therefore will have the same acceptability. This certainly is a desirable objective. However, one must also remember that a dehydrated product may find acceptance because of its own special characteristics which are entirely different from the parent material. Dried prunes, raisins, canned tomato juice, soluble coffee, evaporated milk, and many other items could be cited as examples.

There is one important bottleneck in the development of the dehydration industry which is of utmost importance and deserves some mention at this point. This is the general lack of background or basic research information on the general physical and chemical properties of food under various conditions. This general lack of background information is not peculiar to the dehydration industry. It is also found in nearly every branch of science. If, however, we are to make maximum progress in the development of special food products, much basic research leading into entirely new methods of food processing and preserving must be done. These major advances can come only as we improve our basic understanding of the important properties of food. Basic research in food technology is being conducted and supported on a considerable scale, not only by industry, but by several government agencies as well. These activities should be pushed as rapidly and vigorously as possible.

Food salvage is another facet of food in emergencies which cannot be neglected. The food technologist can be of assistance in this matter. We, in this country, have a tendency to devote only limited attention to this subject. Damaged food is frequently condemned when it could be salvaged for human consumption, or at least for animal food. Should another conflict arise, we may not have food-in-plenty and salvaging damaged food may become a critical operation. The British were able to salvage 75% to 90% of bomb and fire damaged food after methods were developed and a special organization was formed to deal with the problem. Separation of glass splinters, especially from food in bulk storage was one of their big problems.

From what has been related already, it should be obvious that the food technologist has a vital role to play, should this country find itself in another emergency situation. The food technologist must be asked to assist in preparing to meet an emergency, which it is the hope of all will never afflict this country. Yet if we did not prepare now, it may be too late if the emergency does come. The best way of preventing a disaster is to be fully prepared to meet it.

If food technology occupies such a vital role in civil defense plans and preparations, one might logically ask

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why does not the Federal Civil Defense Administration support needed research in solving some of these problems. The answer to this question is obvious to all who have followed the career of the Federal Civil Defense Administration. In the first place, FCDA is a young organization. It was authorized by congress only in January, 1951. It has had tremendous responsibilities to meet with a very limited staff in a very short time. It is only common sense that FCDA's immediate plans and activities must be geared to the current or immediately anticipatable strategic situation, using the facilities and information at hand. FCDA could not wait for several years for research results to become available before making plans to meet a situation which may come tomorrow. In addition, FCDA has had to operate with a very limited budget. It has been able to support practically no research, except that necessary in supporting immediate operational requirements.

Fortunately, many of the food problems which may confront FCDA are now, and have been for some time, problems of concern to the military and to several other Federal Agencies, especially to the Department of Agriculture, which under Executive Order 10161 has primary and overall responsibility for food in defense. These agencies, as well as public organizations, foundations and industry have, and are now supporting research which has already supplied much of the needed information. Many of the food items mentioned have distinct commercial possibilities if generally acceptable products can be developed. These commercial possibilities apply not only to industry but to producers and consumers as well.

The science of food technology has advanced tremendously in the last decade. It is not too much to expect that most of the problems listed in this paper will be resolved within the next few years.

# Frozen Concentrated Milk

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**The factors affecting the flavor and stability of frozen concentrated milk are herein reported and discussed. The problems of marketing the product for domestic consumption in competition with fresh fluid milk are analyzed and the possible market areas are reviewed.**

The storage of dairy products in the frozen state is a relatively old custom. Butter has been stored at temperatures between 0° and —10° F. (—18° and —23° C.), since prior to World War I; the freezing of cream in May and June, for use in ice cream during the period of short milk production in early winter was begun about 1925; concentrated skimmilk has been similarly stored for at least 15 years *(13, 14)*, and commercial ice cream, the first frozen food distributed to consumers, was marketed in Baltimore one hundred years ago. The idea of providing the American household with its daily milk supply, packaged in the frozen state is new, however, dating back only 6 or 7 years. During the later stages of World War II, the Army demonstrated that this would be possible by furnishing frozen fluid milk, in original containers to casualties on hospital ships in foreign waters *(2, 16)*. The product proved just as acceptable as fresh fluid milk and was judged an important morale factor in convalescence by the Medical Corps.

The preparation and distribution of frozen fluid milk is an expensive operation due to the bulk of the product. Consequently, there seems little likelihood that it can be commercialized for domestic utilization. It can only be economically successful where costs are of secondary importance, as was the case in hospital ship use by the Army, where fresh fluid milk cannot be obtained at any price; or where the price of such fresh milk is high enough to permit frozen fluid milk to compete. Such conditions are not found, at present, in the domestic civilian economy.

The possibility of decreasing the expenses of processing and handling frozen milk by removing a substantial portion of the water content, thereby lowering the costs of refrigeration, container, handling, and space has aroused considerable interest in the dairy industry *(4, 8, 11)*. This interest has been enormously stimulated by the phenomenal success of frozen concentrated orange juice since its introduction about 6 years ago and by the wishful thinking of manufacturers of orange-concentrating equipment who have been looking about for other food fields which might expand the use of their machinery. In their enthusiasm the milk industry appeared to offer a great opportunity. Interest in frozen concentrated milk has also been fostered by the Quartermaster Food and Container Institute, both by financially supporting research and by letting it be known that the armed forces are ready to contract for moderate quantities of a satisfactory product.

A considerable amount of research has been carried out on frozen concentrated milk by dairy companies, by colleges, by the Quartermaster Institute, and by the U. S. Bureau of Dairy Industry over the past 10 years. Some work is still in progress. As a result, the problems of processing and of handling and distribution are rather well defined.

## PROBLEMS OF FLAVOR

Concentrated milk, whether fresh or frozen, characteristically has a somewhat flat flavor compared with

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fresh fluid milk *(3, 4, 8)*, possibly due to the removal of some volatile constituents as a result of vacuum condensation. This flavor (or lack of it) is not pronounced and is not greatly objected to by the average person.

A more serious flavor defect, affecting all forms of milk, is that which results from the oxidation of one or more of the lipids (oxidative rancidity). The flavor produced has a tallowy or wet cardboard character and is referred to in the dairy industry by the term oxidized flavor. Frozen concentrated milk is less subject to rapid oxidation than is fluid milk because homogenization and concentration are both antioxidative treatments. Nevertheless, since the frozen product would naturally be held longer before use, the likelihood of oxidized flavor developing cannot be greatly discounted. Fortunately, a simple heat treatment of milk is strongly antioxidative *(4, 8)* and inasmuch as a pasteurizing treatment is obligatory for health reasons, it is a simple matter to employ a somewhat greater degree of heat and obtain flavor protection during frozen storage at the same time bacteriological safety is assured.

Studies have revealed that the heating of milk to temperatures in excess of 167° F. (75° C.), flash, or above 155° F. (68° C.) for 30 minutes causes a release of active sulfide and sulfhydryl groups from some of the sulfur bearing proteins, notably β-lactoglobulin. These —SH groups are strong reducing substances and function as antioxidants, not only toward the milk lipids but also toward ascorbic acid, which is itself a reducing substance. The sulfhydryl substances have been identified, as the source of cooked flavor in heated milk but since they are readily oxidized to a flavorless form, the cooked flavor gradually disappears on holding. It is possible to process frozen concentrated milk using sufficient heat to prevent the development of oxidized flavor but not so much as to result in an objectionable degree of cooked flavor at the time of use *(4, 8)*. A slight amount of cooked flavor in concentrated milk perhaps is desirable because it counteracts the flat flavor previously noted and because milk users have become accustomed to it in pasteurized bottled milk.

Oxidized flavor may also be controlled in frozen concentrated milk by the addition of antioxidants such as ascorbic acid *(1)*, cereal extracts, nordihydroguaiaretic acid, propyl gallate, trypsin, and others. Of course, any method for preventing oxidative deterioration of dairy products presupposes the elimination of such pro-oxidants as copper, iron, and light *(3, 5)*.

## PROBLEMS OF STABILITY

When fluid or concentrated milk is stored frozen, the casein undergoes a slow but progressive loss of stability *(4, 5, 6, 7, 8, 9, 17)*. This is manifested on defrosting by the appearance of a slight granular flocculation which becomes more pronounced as the length of storage increases until, in the last stages, the product exhibits gross coagulation. In concentrated milk the flocculation is usually preceded by a tendency toward gelation during the thawing period *(5, 7)*. The floccules have been shown to be calcium caseinate *(9, 17, 18)* and it is thought that the instability is caused by a dehydration and "salting out" effect resulting from the high concentration of soluble salts in the small amount of unfrozen water.

The frozen storage flocculation of casein is reversible in the early stages *(7, 8, 9)*, with agitation and more especially with heat but in the later stages it is not reversible. Apparently the loss of dispersibility is a physical change involving simple dehydration, at first. On continued holding, however, the dehydrated protein becomes denatured in such a way as to acquire hydrophobic characteristics which interfere with its rehydration *(17)*. Research has shown that soluble calcium accelerates this change in casein during frozen storage but the manner of its involvement is not understood *(9, 12, 18)*.

The limiting factor in the frozen storage of concentrated milk is the rate at which casein loses its ability to be reconstituted in a normal dispersion after defrosting. The loss of stability by the casein is more difficult to postpone than is a deterioration of flavor *(8, 15)*. Flavor can be maintained without significant change for periods up to 6 or 8 months by application of methods previously mentioned but "body stability," at best, cannot be assured for more than 8 to 12 weeks.

It should be pointed out that the storage life of bulk frozen concentrated milk which is to be employed in ice cream manufacture is decidedly longer than would be true for a similar product to be distributed as a frozen food *(13, 14)*. In the former case a considerable degree of casein flocculation is permissible inasmuch as the product will be heated and homogenized in the ice cream mix and the flakiness will disappear. In the latter case, a consumer would immediately look askance on any gelation or flocculation appearing in the defrosted product and would judge it to be spoiled.

Research has revealed several factors which influence the rate of destabilization of casein during frozen storage *(3, 4, 5, 8, 9, 18)*. The greater the concentration of milk solids in the water of the product (higher the concentration ratio) the shorter the period in frozen storage before flocculation becomes evident. Fluid milk has a frozen storage life several times that of three to one concentrated milk which represents about the greatest degree of concentration feasible with a product for retail distribution *(8, 17)*.

Heat treatments up to the equivalent of about 170° F. (76.5° C). for 15 minutes, used for the purpose of pasteurization or for delaying oxidation, have little significant effect on the stability of casein *(9)*, but above this level the frozen storage life of concentrated milk is progressively decreased. Unless there appears to be a considerable likelihood that the milk will oxidize, heat treatments more rigorous than 170° F. (76.5° C.) for 15 minutes should be avoided.

Concentrated milk stored or held at temperatures of —10° F. (—23° C.) will resist flocculation for periods up to three times as long as milk stored at temperatures of 5° F. (—15° C.) *(9)*. The temperature of frozen storage is consequently a very important consideration. The critical point appears to be in the neighborhood of —5° F. (—20.5° C.). All workers are fairly well agreed that frozen concentrated milk should be held at —10° F. (—23° C.) or below if the utilization is delayed beyond a 2- or 3-week period. This temperature is below the customary setting of store cabinets and home freezers.

While fast freezing or agitated freezing of concentrated milk does not seem to be of much significance in prolonging the stability of casein *(8)*, it has been found that the time interval between concentration of the milk and its freezing is an important variable. This is especially true if the product is cooled and held cold in the interval. A short interval with cooling immediately preceding packaging and freezing promotes casein stability. This effect seems to be due to casein structures of a gel type forming while the product is unfrozen, cold and viscous, with the further likelihood that the formation of lactose nuclei may be involved.

One of the most hopeful indications that the storage period of concentrated milk may be further extended is the discovery that calcium ions are highly active in the change which renders the casein non-dispersible *(18)*. Several studies, wherein the

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soluble calcium has been reduced by precipitation, by formation of a complex ion or molecule or by ion-exchange treatment, applied to the milk before freezing have shown greatly extended satisfactory storage periods for the product *(12, 18)*. The main obstacle to the use of ion-exchange resins is the fact that removal of sufficient calcium to be effective results in an objectionable salty or chemical flavor *(18)*. It is believed that more study with various resins and combinations of treatment may overcome this objection *(10, 12)*. The degree of calcium removal accomplished by Zeolite treatment in the preparation of "Sof-Kurd" milk, a product sold commercially in some cities, seems insufficient to greatly benefit frozen concentrated milk.

## PROBLEMS OF MARKETING

The foregoing discussion of the problems concerned with maintenance of flavor and body stability in concentrated milk during frozen storage shows that, from a strictly technological viewpoint, nothing serious stands in the way of marketing a frozen concentrated milk. It is a matter of record that several large dairy companies have publicly announced that they are ready to place the product on the market at any time, should conditions seem to justify it *(11)*. Regardless of how well processing and handling problems have been solved and regardless of how fine in quality a product may be, it will not be successfully marketed unless other factors, particularly economic ones, are also favorable.

The acceptance of frozen concentrated milk by consumers will probably depend on three things, all three important. First, the quality must be substantially equivalent to the fluid milk now available. This point can doubtless be met but the frozen product can never be better than the fluid and, if inadvertently held too long, might be inferior. The dating of packages, giving the time limit for holding would seem to be necessary. Secondly, a product must be relatively convenient to use. In this respect frozen milk would never equal fluid milk which requires no preparation. However, it might enjoy some popularity because of its space saving characteristics, its longer keeping period and the fact that it can be reconstituted to various degrees for different purposes. Finally, the price would be a very important consideration, possibly the most important. A critical examination of the probable costs involved make it highly unlikely that frozen concentrated milk could be sold at a lower equivalent price than that of bottled fluid milk.

It is reasonable to expect that the health authorities of any of the major markets would not permit the sale of frozen concentrated milk unless it adhered in all respects to the requirements and regulations in effect for fluid milk. This would seriously interfere with the production of the product in areas of low cost fluid milk and its subsequent shipment into metropolitan markets. Furthermore, if produced within the milk sheds of the large markets, it seems certain that the milk producer's organizations would insist that the product be included in Class 1, putting the cost of the raw fluid product on a par with that for bottled milk.

The recent failure of fresh bottled concentrated milk in several markets where it was introduced with a great amount of advertising and publicity, bears witness to the importance of the price factor. In Boston where, at first, the price was several cents per quart lower than the equivalent price of fluid milk the sales of the concentrated milk were good and were increasing. Later, after the milk producers had forced its classification into Class 1, the price became about equivalent to fluid milk and sales dropped to a point where manufacturers found it uneconomical to sell.

The lack of appeal of bottled concentrated milk, except on a price differential basis, makes it evident that frozen concentrated milk would fare no better and probably not so well since it is less convenient and must be held under frozen conditions.

This does not mean that frozen concentrated milk is a dead issue or that it has no possible utility. The product has acceptable flavor characteristics; a storage life, when properly processed and held, of about 3 months; and a worth-while reduction of bulk compared with fluid milk. Consequently it would appear well fitted to the role of utilizing surpluses in areas where milk is over produced for shipment to areas lacking a sufficient supply of fresh milk. It has, for instance, been used with some success in providing milk for Alaska, the Canal Zone and, by the Navy, in furnishing remote bases and ships away from sources of supply. Such uses might well be developed further. The probability of frozen concentrated milk competing seriously with fluid bottled milk in domestic markets in the foreseeable future, however, is very small.

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